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JOURNAL OF ECONOMIC ENTOMOLOGY

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The Mode of Action of Petroleum Oils as Ovicides[1,2]

E. H. SMITH[3] and G. W. PEARCE,[4] *New York State Agricultural Experiment Station, Geneva*

Although petroleum oils have long been effectively employed as insecticides, the manner in which they produce their lethal effects is not known. Several possible theories have been proposed such as those indicated by Hoskins (1940) and Martin (1936). It appears that such theories are largely a matter of speculation since little or no direct experimental information is available.

In considering the mode of action of oils when used as ovicides, it has been suggested that the respiratory system is affected in some manner. The present paper is a report on the effect of petroleum oil on the respiratory activity of eggs of the oriental fruit moth, *Grapholitha molesta* (Busck). In addition, data are given on the length of time an oil must be in contact with the egg to prevent hatching. The latter point is of much practical and theoretical value since it is obviously related to the oil deposit weathering factor, the volatility of the oil as well as the mechanism of the killing action.

EXPERIMENTAL METHODS.—*Test Insects*—The oriental fruit moth, *Grapholitha molesta* (Busck), was the principal insect used for the study. This economic species is representative of several which appear to respond identically to oil treatments. Preliminary work was also conducted using eggs of the European red mite, *Paratetranychus pilosus* (C. & F.), and the European corn borer, *Pyrausta nubilalis* (Hubner). Work with these species is incomplete and consequently only data on oriental fruit moth will be given.

MEASUREMENT OF RESPIRATION.—Various types of respirometers were considered including micro-apparatus. The Warburg constant-volume respirometer (Dixon, 1943) proved most readily adaptable for this study. Initial work indicated

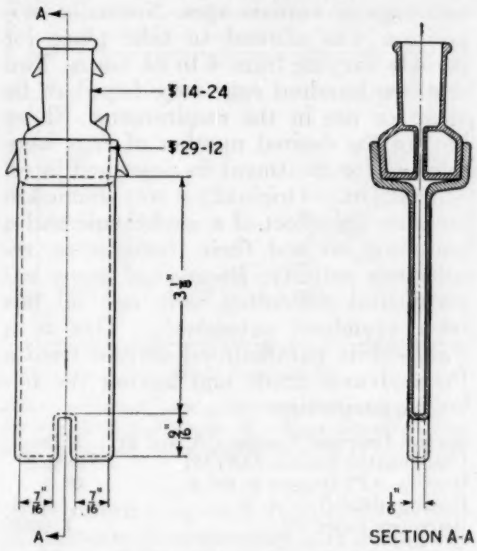

FIG. 1.—Special Warburg respirometer flask designed to hold microscope slides.

that by the use of specially designed flasks with the standard Warburg manometers the hourly oxygen consumption rate of 100 or more oriental fruit moth eggs could be measured with sufficient precision. Accordingly the special flask shown in figure 1 was designed and used in the work to be reported. The flasks were constructed to contain one to three microscope slides (25 mm.×75 mm.×1 mm.) carrying the test eggs keeping the total

Eastern Branch Program—The authors of this paper were awarded the annual prize given for the best paper presented before the Branch on its annual program.

[1] A digest of a thesis submitted to the Graduate School of Cornell Univ. by E. H. Smith Feb. 1948 in partial fulfillment of the requirements for the Ph.D. degree.

[2] Journal Paper No. 748, New York State Agricultural Experiment Station, Jan. 23, 1948.

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volume to a minimum. Total capacity without slides or reagents was approximately 14 cc. The insertion of two slides and addition of the required quantity of liquid in the reservoirs at the bottom (0.3 cc. H_2O and 0.3 cc. 5–10 per cent KOH) reduced the net volume to approximately 8.5 cc. This is considerably less than the standard Warburg flasks available and results in a marked increase in the sensitivity of the respirometer. The flasks were calibrated with mercury according to the procedure outlined by Dixon (1943).

In this initial study, efforts were confined to the measurement of the oxygen consumption rate of treated and untreated eggs of approximately known age. Moths at the peak of their oviposition activity (4 to 5 days old) were induced to lay eggs on the microscope slides forming one side of a small cage. The slides could be removed at any time interval desired to obtain eggs of various ages. Normally oviposition was allowed to take place for periods varying from 4 to 24 hours. Two or three hundred eggs were found to be ideal for use in the respirometer. Slides having the desired number of eggs were selected for treatment as described later.

TEST OIL.—Originally it was planned to measure the effect of a naphthenic and a paraffinic oil and their fractions on respiratory activity. Because of many experimental difficulties only one oil has been examined extensively. This is a water-white paraffinic oil derived from a Pennsylvania crude and having the following properties:

Saybolt Universal Viscosity at 100° F.	65 Sec.
Unsulfonated Residue (ASTM)	98%
Gravity, API Degrees at 60° F.	36.5
Density, d20/4°	.8384
Refractive Index n_D^{20}	1.4632

This oil has been given the code number *46-M20* and is identical with oil *42-M20* included in the work of Pearce *et al.* (1948) except that it is from a different year's manufacture. Oil *46-M20* and its fractions are being studied in an extensive program of research on spray oils at the Geneva Station. Because a large amount of insecticidal data will eventually be available on this oil it was considered advantageous to employ it in the present study.

APPLICATION OF TEST OIL.—Since it was desired to study the effects of lethal as well as sub-lethal dosages of the oil, methods of controlling and determining deposition rate on the glass slides were necessary. It was found very difficult to spray the slides directly and obtain reproducible deposits. After much experimentation a settling tower technique was adopted. In this procedure the concentration of oil in the spray was kept constant and the time of treatment altered. By varying the time from 30 seconds to 6 minutes, the desired range of deposit was obtained with good reproducibility. The mist-like spray deposit obtained was completely dry in a few minutes permitting the measurement of respiration with minimum delay following treatment. Normally, the oil spray was made at a concentration of 2 per cent using blood albumin as emulsifier at the rate of 2 oz. per 100 gallons of spray. The mixture was emulsified by use of a hand homogenizer.

The amount of oil deposited on the slides per unit of area was determined by the colorimetric method of Pearce & Avens (1943). The data are expressed in terms of milligrams per 100 sq. cm. of surface. When treating slides containing egg samples extra slides were treated simultaneously for oil deposit analysis.

MINIMUM EFFECTIVE DOSAGE.—The minimum effective dosage (M.E.D.) is defined as the "milligrams of oil per 100 sq. cm. of host surface required to produce a control efficiency of 95 per cent." In the present study an M.E.D. value of 1.5 mg. was obtained for the test oil. This value was determined using eggs in the earlier stages of their incubation period. It will be seen later that the eggs show an increasing resistance to oil during the last part of their incubation. The M.E.D. found above applies to a host surface of glass and an incubation period of 3 to 4 days. Pearce *et al.* (1948) found a value of 2.9 mgs. for the same oil using quince foliage as the host surface and an incubation period of 7 to 10 days. The higher M.E.D. value obtained in the latter case is believed due mainly to the differences in host surfaces and incubation periods.

EXPERIMENTAL RESULTS.—*Normal Respiratory Rate*—In order to determine the effect of oil treatments on the respiratory rate of developing eggs, it was first necessary to determine the normal rate. This was done by making frequent determinations of respiratory rate of eggs in various

stages of development and plotting the readings against age of the eggs. All determinations were made at 80° F., and the results are expressed as cubic millimeters of oxygen per 100 eggs per hour. According to Peterson (1930), 110 effective day degrees are required to complete incubation of oriental fruit moth eggs. (Thus, the incubation period required approximately 88 hours at 80° F.) Two to three hundred eggs laid in a 12-hour period were used in making each determination. The hatch in these eggs was slightly over 85 per cent. No effort was made to correct for natural mortality as the respiratory activity of infertile eggs and partially developed eggs was not known.

In making continuous hourly determinations of respiratory rate, it was found that the rate varied slightly from hour to hour. These variations were greater than could be accounted for by the inherent error in the technique used. The consistency of this variation would seem to indicate that such fluctuation is normal in developing eggs. The following readings are typical of the variations found in hourly readings:

Hours	*MM³ O₂/100 eggs*
1st	3.22
2nd	3.95
3rd	3.64
Average	3.60

The lower curve shown in figure 2 was fitted by eye to the points determined in the manner described above. This curve represents the average of eggs of mixed age. It will be seen from the curve that during the first two-thirds of the incubation period the increase in respiratory activity is slight. Beyond that point the rate increases rapidly until hatching. This rapid increase in respiratory rate is coincident with the development of the embryo to the point that the outline of the head capsule is barely visible when observed through a binocular microscope. This stage of development is followed in a few hours by the stage commonly referred to as the "black-spot" stage in which the head capsule is readily apparent as a dark spot.

An exact determination of the respiratory rate was difficult when using eggs which varied as much as 12 hours in age. In such cases hatching extended over a period greater than 12 hours and the respiratory activity of hatched larva no doubt introduced some error. To overcome this possible error, rate determinations were made on eggs laid during a 3-hour period. Readings were taken only every 24 hours throughout the first two-thirds of the incubation period and more frequently during the final stages. The results are illustrated by the upper

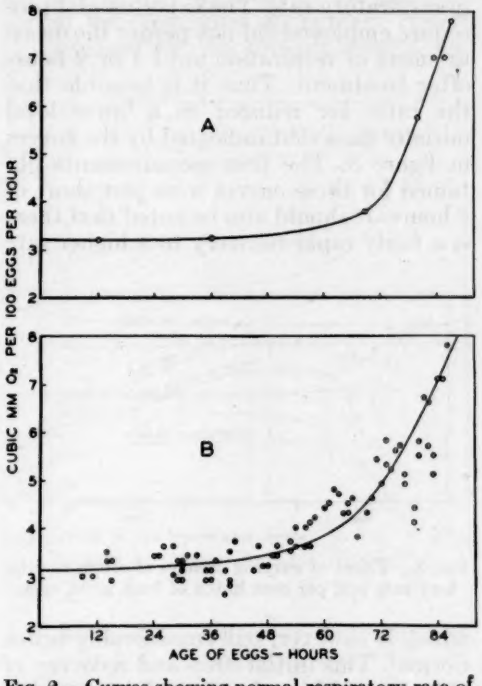

FIG. 2.—Curves showing normal respiratory rate of oriental fruit moth eggs. A.—Eggs deposited over 3 hr. period. B.—Eggs deposited over 12 hr. period.

curve shown in figure 2. It will be seen that the increase in respiratory rate during the final stage of incubation is steeper than in the lower curve representing groups of eggs of a wider range in age. Moreover, less change in rate occurs during the earlier stages of incubation. Even in eggs differing in age by no more than 3 hours there was a considerable spread in the time of hatching. It is doubtful, however, whether further reduction in the range in age of the eggs would change the upper curve (Fig. 2) substantially. It is considered, therefore, that the upper curve in figure 2 represents the normal average oxygen consumption rate of oriental fruit

moth eggs throughout their incubation period at a temperature of 80° F.

EFFECT OF OIL ON RESPIRATORY RATE.—A typical set of data showing the effects of lethal and sub-lethal dosages of oil are shown in figure 3. The per cent hatch as well as the dosage in milligrams per 100 sq. cm. is shown on each curve, the top curve being the normal oxygen consumption rate of an untreated group of eggs. It is noted that the immediate effect of the oil in all cases is a sharp decrease in respiratory rate. The experimental procedure employed did not permit the measurement of respiration until 1 or 2 hours after treatment. Thus it is possible that the rates are reduced to a lower level initially than that indicated by the curves in figure 3. The first measurements obtained for these curves were just short of 2 hours. It should also be noted that there is a fairly rapid recovery to a higher rate

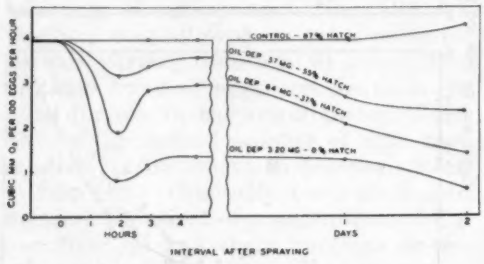
CUBIC MM O_2 PER 100 EGGS PER HOUR
CONTROL - 87% HATCH
OIL DEP. 37 MG - 59% HATCH
OIL DEP. 84 MG - 37% HATCH
OIL DEP. 320 MG - 0% HATCH
HOURS
DAYS
INTERVAL AFTER SPRAYING

FIG. 3.—Effect of varying dosages of oil on respiratory rate and per cent hatch of fruit moth eggs.

which is however, still considerably below normal. This initial drop and recovery of the rate within the first 3 hours after treatment is believed to be a direct mechanical effect on the gaseous exchange equilibrium in operation before treatment. Thus, the sudden deposition of a film of oil on the egg surface would be expected to depress gas exchange sharply at first with a gradual recovery to a new equilibrium condition. In any event, evidence given in a later section (Speed of Kill) indicates that this initial depression in respiratory rate is not responsible for the eventual lethal effect of the oil. Presumably, then, the behavior of the curves in figure 3 after the initial effects is related to the lethal action of the oil. Again, evidence that this is the case is given in the section referred to above.

Irrespective of the ultimate explanation of the effect of oil on the respiratory rate the data presented in figure 3 are of interest for other reasons. In particular, a correlation between control efficiency, dosage and depression of respiratory rate is evident. Thus, a knowledge of the magnitude of any of the three factors would enable one to estimate the value for the other two. The accuracy of such estimations, of course, will depend partly on the precision and reproducibility of the basic curves relating all three variables.

A number of general observations were made in connection with embryo development which are believed to be of significance in relation to figure 3. Of perhaps greatest interest is the fact that respiratory activity of eggs receiving lethal dosages of oil continues long after the normal time of hatching. Concentrations of oil twelve times that required for 100 per cent mortality failed to stop all respiration immediately. In cases where the dosage was sub-lethal or just barely lethal some eggs developed to the "black-spot" stage although only partial or no hatching occurred. It was apparent that as the oil dosage was reduced, more and more eggs reached the "black-spot" stage. It is of interest to note that Lipp (1929) observed development of oriental fruit moth eggs to the "black-spot" stage when they had been treated with lethal dosages of linseed oil. In the present study of eggs treated with lethal dosages after the "black-spot" stage had been reached it was possible to observe peristaltic movement in the embryo for several days after the normal hatching time. The foregoing observations strongly indicate that it is not readily apparent when death of treated eggs takes place. Life is clearly evident long after normal hatching would have occurred.

Further evidence of continued activity of the eggs after receiving lethal dosages of oil was obtained through the use of 2, 3, 5 triphenyltetrazolium chloride. Porter *et al.* (1947) used this compound with success in testing the germinating ability of certain seeds. Mattson *et al.* (1947) outline the historical background and properties of this material as an agent for detecting viability in living tissues. According to the latter workers, the colorless triphenyltetrazolium chloride is reduced by viable tissue to insoluble red triphenyl formazan. Enzyme systems are evidently responsible since heated (82° C.

or above) tissues fail to reduce the compound.

In applying the test for viability slides bearing eggs were placed in a petri dish and covered with a 2 per cent solution of the tetrazolium. With the aid of a binocular microscope each egg to be examined was carefully pierced with a needle to insure contact between the egg contents and the indicator solution. Eggs treated in this manner were held in a dark cabinet at room temperature for 2 to 8 hours. They were then examined for the presence or intensity of the red color characteristic of the reduced form of the indicator. Eggs receiving no oil treatment stained a bright carmine red with few exceptions. Oil treated eggs also showed a red color but of less intensity. It was clearly evident that the intensity of the color decreased as the time interval after treatment increased, thus indicating that the oil was slowly reducing the activity of the egg but not completely stopping it. On the other hand, eggs inactivated by brief immersion in hot water failed to show any red color development even when subjected to the indicator test immediately after heat treatment. The results of the viability tests with tetrazolium are in complete agreement with the respiratory rate curves shown in figure 3.

SUSCEPTIBILITY OF EGGS AT VARIOUS STAGES OF DEVELOPMENT.—When eggs at different stages of development were treated with sub-lethal dosages of oil the resulting hatch indicated a difference in susceptibility. To determine this difference four groups of eggs, with a difference in age of 12 hours between each group, were collected. By applying varying sublethal dosages of oil to eggs collected in this manner the relative difference in susceptibility became apparent. Figure 4 presents a summary of the data obtained. For comparative purposes the normal respiration curve is included at the top of this figure. The series of curves at the bottom show the resulting hatch when eggs of different age are treated with various dosages of oil. The average age of each group at time of treatment is plotted against per cent hatch. It is evident from figure 4 that the eggs show no significant difference in susceptibility during the first two-thirds of their incubation. However, an increasing resistance to the oil is shown in the last third of the incubation period. Thus, the high respiratory rate, characteristic of the eggs just before hatching begins, coincides with the most resistant period of the eggs.

It should be emphasized that differences in susceptibility do not appear if dosages substantially in excess of the M.E.D. are employed. Under these conditions 95 to 100 per cent kill occurs regardless of the age of the eggs. This suggests an explanation for the variable results obtained by others. The decrease in susceptibility with age of the eggs observed by Newcomer & Yothers (1932) is confirmed by the present results. On

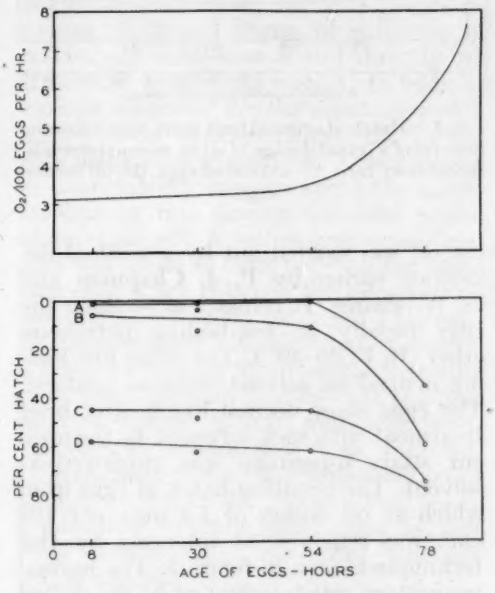

FIG. 4.—Relation of age of oriental fruit moth eggs to their susceptibility to oil treatment. (*Top*) Normal respiratory rate. (*Bottom*) Hatch of eggs 8, 30, 54 and 78 hours old when treated with four different dosages of oil: A—1.4, B—1.2, C—0.6, D—0.5 mgs. per 100 sq. cm.

the other hand, Hough & Jefferson (1936) could not demonstrate a consistent relation between age of the eggs and susceptibility. It is possible that the latter workers were employing excessive dosages of oil in many of their tests which of course would make their results difficult to interpret.

SPEED OF KILL.—As previously shown, treatment with oil resulted in a reduction in respiratory rate, the heavier dosages producing a greater reduction in rate and this reduced rate continued even beyond

the normal time of hatching of untreated eggs. There was then no clearly defined point at which the eggs could be considered dead. This observation posed the question: Was the lethal effect of oil treatment a result of the sudden initial depression in respiratory rate, or was it related to the continued sub-normal rate? To determine this point, oil was removed from treated eggs at various intervals and the resulting hatch observed. Removal of

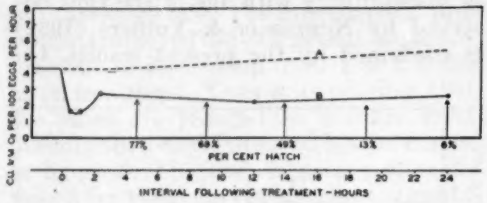

FIG. 5.—Hatch of oriental fruit moth eggs following removal of a lethal dosage of oil at various intervals. Respiratory rate: A—untreated eggs. B—oil treated eggs.

the oil was carried out by a method developed earlier by P. J. Chapman and G. W. Pearce. It consists of washing the eggs rapidly in low-boiling petroleum ether (B. P. 20–40° C.) or other low-boiling neutral oil solvent, such as pentane. The eggs show normal hatch after brief treatment with such solvents. In the present study n-pentane was employed as solvent. The resulting hatch of eggs from which an oil dosage of 1.5 mgs. per 100 cm^2. was removed at intervals by this technique is seen in figure 5. The normal respiratory rate is indicated by the dotted line and the rate determined for treated eggs is shown as a solid line. The per cent hatch after removal of the same dosage of oil from eggs at various intervals is shown along the X-axis. It will be noted that the sudden initial depression in respiratory rate at time of treatment accounted for little or no mortality and that the mortality resulting from oil treatment varied with the duration of contact between the oil and eggs. This indicates that the continued suppression of the respiratory rate by the oil is directly related to the killing mechanism.

Following the above observations it was of interest to determine whether there was any marked difference in time of kill between a dosage greatly in excess of the minimum effective dosage (M.E.D.) for the oil and one fairly close to the M.E.D. Such an experiment was carried out and the results are summarized in figure 6. It is seen that the heavier deposit produced a more rapid lethal action, although the ultimate result at the end of 24 hours of exposure to the oil is about equal. Thus, it may be assumed that when a dosage equivalent to or in excess of the M.E.D. for the oil is present for 24 hours, 95 to 100 per cent mortality will occur. If losses due to weathering or volatilization reduce the dosage below the M.E.D. during the first 24 hours after treatment reduction in efficiency may be expected.

Another point on which the experiments in this section have some significance concerns the question of penetration of oils into insect eggs. This question has been studied by others (Fox 1930; O'Kane & Baker 1935; Powers & Headlee 1939) with variable results and conclusions. It is believed that the fact demonstrated here that oils can be removed from eggs by a simple washing with a solvent without any apparent affect on the viability of the eggs is pertinent. For if marked penetration of the egg chorion occurs then removal with a solvent would be

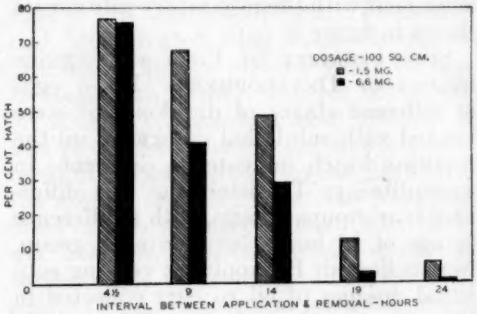

FIG. 6.—Speed of kill of oriental fruit moth eggs receiving a minimum effective dosage (1.5 mg.) and an excessive dosage of oil.

difficult without deleterious effects on the egg. Apparently, the oil exerts its lethal effect without penetration and, although penetration evidently occurs by prolonged immersion (O'Kane & Baker 1935) it is not essential to affect kill.

DISCUSSION.—The results of this study show that the normal respiratory activity of developing eggs is markedly reduced by oil. Moreover, prolonged reduction of normal activity by the oil is apparently directly related to the lethal action. It

also would appear that the lethal action consists of a slow reduction in vitality of the egg with no sharply defined point of death. These observations strongly suggest that the oil exerts its lethal effect through a mechanical interference with the normal gaseous exchange mechanism. Just how such interference eventually produces death is unknown. At this point the writers would like to call attention to an experimental observation which may be highly significant. In the course of the respiration studies it was noted that prolonged enclosure of untreated eggs in the respirometer resulted in reduced hatch and in extreme cases total kill. Intermittent aeration of the flasks between rate measurements was a sufficient precaution to prevent any mortality from this source. Calculations showed that the oxygen supply in the closed system was adequate, therefore, oxygen improverishment was not the cause of mortality. The carbon dioxide produced by the eggs was effectively absorbed by the KOH solution present in the bottom of the flasks so that no toxic effect could be attributed to the accumulation of carbon dioxide. The only logical explanation for the mortality, then, would seem to be that one or more gaseous metabolic products were being produced by the eggs which, if allowed to accumulate, would eventually result in death of the eggs. Assuming that a toxic substance is produced it is reasonable to suppose that a film of oil on the surface of the egg would cause the accumulation of the metabolite within the egg by preventing its ready elimination through the chorion. Such a theory could well explain most of the phenomena observed in the present study.

While the foregoing hypothesis has some basis in experimental observation it is felt that additional evidence is needed to establish the existence of any toxic metabolite as the direct lethal agent involved in the ovicidal action of petroleum oils.

SUMMARY.—The respiratory rate of eggs of the oriental fruit moth, *Grapholitha molesta* (Busck), was found to be relatively constant during the first two-thirds of the incubation period, rising sharply during the final period. The effect of oil on the respiratory rate was found to be an immediate marked reduction in activity with a relatively quick recovery to a rate still below normal. The control efficiency, dosage of oil and degree of reduction of respiratory rate were found directly related. Oil treatments applied to eggs at various stages of development showed a variation in susceptibility, the oldest eggs being least susceptible. This decrease in susceptibility coincided with the higher respiratory rate during the final period of development. A rather precise relationship was found to exist between the duration of contact between the eggs and oil and the hatch which followed. This relationship could be demonstrated by removing oils from eggs at intervals following treatment. Some indication that the eggs produce a toxic gaseous metabolic product during development was obtained. It is suggested that the ovicidal action of oil may be due to the prevention of ready elimination of toxic metabolites causing their accumulation in lethal amounts within the egg.[1]

[1] Acknowledgements: The writers wish to express their appreciation to Dr. P. J. Chapman whose interest and suggestions have contributed greatly to this study, and to Talmage G. Campbell for his diligent assistance in carrying out much of the experimental work. Thanks are also due to the Shell Oil Co. for a grant-in-aid which has covered a part of the expense of the investigation.

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The Application of Dormant Oils as Mists[1]

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The application of oil insecticides to apples in the dormant or delayed dormant period is often one of the most difficult treatments for fruit growers to make. Adverse weather conditions, soft ground, and heavy, slow-moving equipment often make it impossible to cover orchards in the relatively short time available. The hope of alleviating this situation seems to lie in the recent development of improved insecticides and equipment, especially in those which lend themselves to application in concentrated form. The application

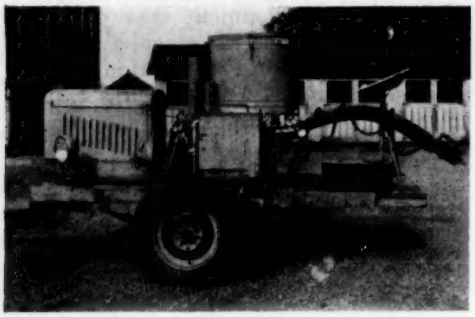

FIG. 1.—Mist sprayer showing relation of pump, liquid tank and blower to nozzle.

of oil concentrates as pure oil, as oil-in-water or as water-in-oil emulsions is not new. Parker (1933) reported that he had developed this technique of using an air stream to carry finely atomized oil as early as 1931. In his first tests, he successfully used an undiluted phytonomic summer oil against the grape leaf hopper. Later he found that the addition of a toxicant, such as pyrethrum, to the oil increased its efficiency and also that a water-in-oil emulsion, containing as high as 75 per cent water, extended the material to give better coverage and caused less injury to the plants. Since that time, numerous investigators have rendered valuable service in improving the materials, equipment, and technique for this type of application. Most of this developmental work seems to have been done in the west. The commercial names given this technique, such as "vapo-dusting," "vapor spraying," "liquid dusting," misting or fogging are practically synonymous in so far as the basic principal is concerned. All employ machines in which highly concentrated suspensions or solutions of insecticides are broken up into fine particles, diluted with air and carried to the trees in an air stream. Because the term "mist" seems more nearly to fit the product of such machines it will be used in this paper.

The experiments here in reported were carried out during the seasons of 1946 and 1947 on apple orchards in the mid-Hudson Valley of New York State. Although the investigations have not been extensive enough to warrant definite recommendations, the data obtained may be useful to other workers in this field. Inasmuch as the equipment, materials, and technique used seem to have a bearing on the efficiency of concentrate application, a brief description of each follows.

The mist treatments were applied with a machine developed as a cooperative project between the U.S.D.A., Bureau of

Eastern Branch Program.
[1] Journal Paper No. 735, New York State Agricultural Experiment Station, Geneva, New York (Dec. 9, 1947).

Entomology and Plant Quarantine and the New York State Agricultural Experiment Station (Fig. 1). It consisted basically of a duster[1] which was fitted with a 3 gallon per minute pump[2] and a 12-gallon tank with a mechanical agitator. The air was discharged through a 4-inch outlet at a velocity of approximately 200 miles per hour. Thus, the machine would be considered as a low-volume high-velocity type. While the pump was capable of developing 250 pounds of pressure, the liquids were injected into the air stream at 100 pounds per square inch through a single nozzle mounted in the center of and about 1 inch beyond the end of the air tube. This nozzle, which delivered a conical spray, was directed at an angle of 180 degrees to the air blast. This reversed type of injection seemed to give the best break-up of the particles as well as an even distribution in the air stream. The position of the nozzle is important. When the cone of liquid is introduced too far in front of the air tube the mist is largely confined to the center of the air stream. On the other hand, if it is too close, the liquid may contact the rim of the air tube thereby producing a ring of larger droplets.

During the 1946 season, the nozzles used were of the whirl-plate type delivering a solid cone.[3] However, since the rate of delivery of such nozzles is fixed for a given pressure, it was necessary to change the nozzle whenever the rate of application was to be varied. Furthermore, nozzles of this type delivering less than 2 gallons per minute, tended to clog when used with certain materials. By 1947, a new type of liquid injector[4] had been perfected by the senior author which made it possible to vary the rate of liquid discharge by means of a simple flow valve, without changing the nozzle or affecting the pressure. An injector of this type, adjusted to deliver the liquid at 100 pounds pressure, was carefully calibrated with a flow valve and was used in all the 1947 experiments (Fig. 2).

The conventional spray treatments used for comparison studies in most of the experiments were applied with a standard orchard sprayer developing 500 pounds pressure per square inch and a single spray gun.[5] The trees treated with this machine were sprayed from the ground only.

Since we were interested in the efficiency of the method of application, rather than the performance of materials, a single dormant-type paraffinic oil[6] was used in all tests. The specifications for this oil fall within the limits of those of the superior type dormant spray oi lestablished by Pearce *et al.* (1942) as follows:

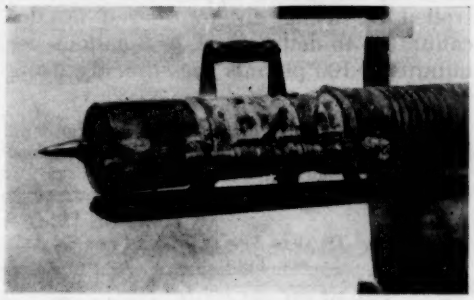

FIG. 2.—Close up of mist nozzle showing position of liquid injector in relation to air discharge tube. Flow valve on left and shut-off valve on right.

Specifications for Dormant Type Spray Oils	
Viscosity (Saybolt at 100° F.)	90–120 seconds
Viscosity Index (Kinematic)	100 minimum
Gravity (A.P.I. degrees)	32 minimum
Unsulfonated residue (per cent)	90–92
Homogeneity	A relatively narrow boiling distillate portion of petroleum
Pour Point	Not greater than 30° F.

To eliminate differences which might be attributed to the emulsifier or the method of making the emulsions, a standard procedure was adopted. It consisted of first mixing 1.5 per cent of spreader[7] with the oil. The desired amount of this combination was then added to 4 gallons of water in the spray tank with the agitator running. After passing the material through the pump and a small nozzle and back into the tank for 2 minutes, the tank was filled to 12 gallons and the liquid supply line flushed with the diluted emulsion before making the application. This procedure produced a relatively quick-breaking oil-in-water emulsion.

The mist treatments were applied to both sides of each row as the equipment moved through the orchard at a speed of

[1] *Niagara Direct Drive.*
[2] *Bean Duplex.*
[3] Purchased from the Spraying Systems Company, Chicago, Illinois.
[4] The possibilities of patenting this injector are now being investigated.
[5] *Friend Pecan.*
[6] *Sovaspray #2*, manufactured by the Socony Vacuum Oil Company.
[7] *Triton B1956* an emulsifier manufactured by Rohm Haas & Company.

about 2 miles per hour. The nozzle was manually directed to give as complete a coverage of the trees as possible. In general, it was found desirable to keep the nozzle at least 5 feet away from the nearest limbs while making the treatments. This gave the particles time to disperse into a more uniform cloud and reduced the danger of over-treating nearby limbs. In 1946, the rate of application was controlled by using different sized nozzles calibrated to deliver 1, 2, or 3 gallons per minute at 100 pounds pressure. By using the new type of injector in 1947, the rate was varied by adjusting a calibrated flow valve inserted in the fluid supply line just behind the nozzle.

Table 1.—Relation of oil concentration and rate of application to oil deposit when applied with the mist sprayer—1946 Series.

Oil Concentration	Quarts Applied per Tree		Mg. Oil Deposited per Sq. In. of Bark	
	Emulsion	Oil	Lower Limbs	Tree Tops
3.12%	7.80	0.24	0.43	
6.25%	3.33	0.21	0.38	
12.50%	2.67	0.33	0.63	
25.00%	3.20	0.80	1.29	0.89
25.00%	9.50	2.37	2.33	1.79
50.00%	6.00	3.00	2.62	
100.00%	1.67	1.67	2.33	

Five medium to large McIntosh trees about 25 years of age used for each treatment.

After each treatment, the amount of material used was determined and the number of quarts used per tree calculated. As soon as the bark appeared dry, twig samples were taken from which the milligrams of oil deposited per square inch of bark sulface were determined in the manner reported by Pearce *et al.* (1941). All treatments were made in the green tip or delayed dormant stage of bud development.

In certain tests, European red mite, *Paratetranychus pilosus*, C&F, control data were taken which were based on the percentage of overwintering eggs hatching the numbers of mites per leaf later in the season, or by both methods. All mite control data were compared with similar counts on untreated trees made on the same dates.

The data herein reported are grouped to bring out certain pertinent observations rather than in chronological order. The preliminary work in 1946 indicated several trends which guided later studies. It was found (1) that the amount of oil per tree necessary to produce a given oil deposit on the bark was less in the case of mists than in the case of conventional high pressure sprays; (2) that, for the equipment used, the deposit from undiluted oils was uneven, resulting in a dangerously high residue on the lower limbs; (3) that oil-in-water emulsions of the type used which contained more than 30 per cent oil were too viscous to handle well in the pump and failed to break up into fine enough particles to give an even distribution on the bark.

In 1946 and 1947 series of tests were made to determine the effect of oil concentration and rate of application on the amount of oil deposited. Although carried out in different orchards in the 2 years the trees were similar, except that those used in 1947 were slightly larger. In both instances they were medium to large McIntosh about 25 years of age. The results of the 1946 experiment are summarized in table 1. When the 3.12 per cent oil emulsion was applied at approximately twice the rate of the 6.25 per cent material, the oil deposits were similar and in proportion to the amount of actual oil used per tree. Likewise when the 6.25 per cent, the 12.5 per cent and the 25 per cent oil emulsions were applied at nearly the same rate per tree, the deposit was in proportion to the amount of actual oil used. Similarly, tripling the amount of 25 per cent emulsion used per tree doubled

Table 2.—Relation of oil concentration and rate of application to oil deposit when applied with the mist sprayer—1947 Series.

Oil Concentration	Application Rate	Quarts per Tree		Mg. Oil Deposited per Sq. In. of Bark	
Per Cent	Gals. per Minute	Emulsion	Oil	Lower Limbs	Tree Top
6.25	1	3.00	0.19	0.08	—
6.25	2	5.50	0.34	0.48	—
6.25	3	8.00	0.50	0.65	—
12.50	1	2.25	0.28	0.38	—
12.50	2	5.66	0.71	1.00	—
12.50	3	8.00	1.00	1.62	—
25.00	1	3.30	0.82	1.19	1.19
25.00	2	5.50	1.38	2.03	1.68
25.00	3	7.50	1.88	2.43	2.02
100.00	1	2.66	2.66	2.27	—

Four medium to large McIntosh trees about 25 years of age used for each treatment.

the deposit obtained. Because of the viscous nature of the 50 per cent material, it was necessary to apply it with a nozzle having a larger orifice. This produced a mist of relatively larger particle size and tended to give a spotty deposit on the bark. The undiluted oil performed satisfactorily with the regular injectors, but it gave a very heavy deposit on the limbs nearest the nozzle which caused severe injury to the buds.

The 1947 series was more extensive and the data, presented in table 2, support the 1946 results. The deposits obtained paralleled very closely the amount of actual oil applied per tree. Between the concentrations of 6.25 per cent and 25 per cent emulsions there was little or no difference in the deposit laid down per unit of oil applied. On trees of equal size, the deposit was determined by the amount of actual oil applied, regardless of the concentration used. Wherever twig samples were taken from the tree tops, the oil deposit equalled at least 70 per cent of the deposit found on samples taken at shoulder height. This variation in oil deposit between the top and bottom of the tree is essentially the same as that which results from conventional spraying.

Table 3 represents data taken from a large scale experiment, involving blocks of 30 to 40 trees each, in which two oil concentrations applied as mists were compared with a standard spray treatment with a 3 per cent oil emulsion. In the mist application the correlation between the amount of actual oil applied and the deposit is obtained apparent. With the conventional spray the amount of actual oil per tree necessary to attain a given deposit on the bark is about twice that needed for the mist application. This may by explained in part on the basis of the run-off experienced in the conventional applications or it may be due to a relatively lighter deposit laid down on the trunks and scaffold limbs by the mist applications.

To check the reproducibility of the results obtained on the rate of application, oil deposit, and European red mite control, an orchard treated in 1946 was treated with the same series of concentrations and on the same plots in 1947. This, an 11-year-old Kendall orchard pro-

Table 3.—Results of large scale experiment showing relation of oil concentration and rate of application to oil deposit—1947.

Oil Concentration	Quarts Applied per Tree		Mg. Oil Deposited per Sq. In. of Bark
	Emulsion	Oil	
12.50% Mist	4.84	0.60	1.18
25.00% Mist	4.89	1.22	2.19
3.00% Spray	38.46	1.15	1.50

Thirty to forty medium to large apple trees of several varieties used for each treatment.
Deposit data taken on N. Western Greening variety.

Table 4.—Two years experimentation—conventional sprays versus mists in the same orchard.

Oil Concentration, Per Cent	Type of Application	Year Applied	Quarts per Tree		Mg. Oil per Sq. In. of Bark	Mites per 100 Leaves			
			Emulsion	Oil		6/17	Per Cent Reduction	8/14/46[1] or 7/14/47[1]	Per Cent Reduction
6.25	Mist	1946	1.5	0.09	0.48	26	97.4	1771	43.6
		1947	1.9	0.12	0.55	—		2211	60.2
12.50	Mist	1946	1.5	0.18	1.59	1	99.9	242	92.3
		1947	1.6	0.20	1.64	—		1404	74.7
25.0	Mist	1946	1.2	0.30	2.08	3	99.7	30	99.4
		1947	1.6	0.39	2.99	—		216	96.1
2.00	Spray	1946	24.1	0.48	1.13	9	99.1	970	69.1
3.00		1947	33.3	1.00	1.28	—		534	90.4
Control	None	1946	—	—	—	994	—	3140	—
		1947	—	—	—	—	—	5553	—

[1] Counts made at approximately the peak of the red mite populations.
Twelve to 22 11-year old Kendall trees used for each treatment.
Control data based on similar counts made in the untreated plots on the same dates.

ducing an average of 8 bushels of apples per tree in 1947, was divided into blocks of from 12 to 22 trees each and treated as indicated in table 4. In both years, a close correlation was obtained between the amount of actual oil applied and the amount deposited, in addition to a close correlation between the oil deposit and coverage of the trees was obtained with these treatments. No injury was observed on any of the treated trees beyond a slight retardation of bud development in the case of the trees misted with the 25 per cent oil emulsion.

Table 5 summarizes the results obtained in a Red Delicious orchard treated in

Table 5.—Relation of oil concentration and rate of application to oil deposit and European red mite control—1947.

Oil Concentration	Quarts per Tree		Mg. Oil per Sq. In. of Bark	Per Cent Control Overwintering Eggs	Eggs per 100 Leaves July 11	
	Emulsion	Oil			Eggs	Per Cent Reduction
6.25% Mist	6.00	0.38	1.04	87.6	1195	17.3
12.50% Mist	4.00	0.50	1.53	95.9	129	91.1
25.00% Mist	2.52	0.63	1.52	100.0	31	97.8
3.00% Spray	50.00	1.50	1.73	99.6	74	94.8
Control None	—	—	—	—	1445	—

Blocks consisting of 4×5 trees each used for each treatment.

the degree of red mite control. The data on red mite control for August 1946 and July 1947 were selected as being at approximately the peak of the red mite populations. In both years, the infestation in this particular orchard dropped to a very low level following the counts. No counts were made on the per cent kill of overwintering eggs in these experiments, but the fact that the summer mite populations remained low in the mist-treated plots indicated that rather complete

Table 6.—Relation of oil concentrations and rate of application to oil deposit and the control of overwintering red mite eggs—1947.

Oil Concentration	Quarts per Tree		Mg. Oil per Sq. In. of Bark	Per Cent Control Overwintering Eggs
	Emulsion	Oil		
12.50% Mist	3.5	0.44	1.21	99.1
25.00% Mist	2.8	0.70	1.52	99.4
3.00% Spray	37.5	1.12	1.35	99.4

Table 7.—Seasonal build-up of European red mite populations following delayed dormant mist and spray treatments—1947.

Mg. Oil per Sq. In. of Bark	Mites per 100 Leaves					
	July 11		Aug. 8		Sept. 9	
	Mites	Eggs	Mites	Eggs	Mites	Eggs
1.21	34	11	216	288	2067	1227
1.52	41	13	767	1509	1597	908
1.35	15	3	79	74	1842	1488
None	2136	737	9127	5215	46	134

1947. The plots in this experiment consisted of 20 trees arranged in unreplicated blocks of 4 by 5 trees each. In this case, an attempt was made to adjust the rate of application of each concentration to obtain an oil deposit sufficient to give commercial control of the overwintering red mite eggs. Thus, the rate of application was decreased as the oil concentration in the mists was increased. Because of the difficulty met in keeping a constant tractor speed on sloping terrain, the results were not as accurate as desired. However, the correlation between the amount of oil used per tree, the oil deposit on the bark and the kill of overwintering eggs is reasonably close. It was unfortunate that a heavy infestation of the two-spotted mite, *Tetranychus bimaculatus*, Harvey, developed in this orchard prior to the July 11 leaf count. It was impractical to try to differentiate between the active stages of these two species of mites and the data were taken on the basis of the European red mite eggs present. The fact that the red mite control persisted through mid-summer indicates a rather complete coverage of the trees with the oil treatments.

Another Red Delicious orchard, very heavily infested with overwintering mite eggs, was divided into three plots of 8 to 12 trees each and treated in 1947. Tables 6 and 7 present a résumé of the

data obtained from this experiment. Due to the wet condition of the ground, some difficulty was experienced in making the 25 per cent oil mist application. This is reflected in the red mite counts made on the foliage later in the season. The correlation between the amount of oil applied per tree, the oil deposit, and the control of overwintering mite eggs followed very closely that obtained in the other tests. The later divergence can be explained by a series of observations made at intervals during the spring and summer. As indicated, these trees were heavily infested with overwintering red mite eggs so that there was an abundance of these eggs on the trunk and scaffold limbs, especially under the loose bark and in cracks and crevices. When leaf samples were taken on July 11, it was observed that mites were numerous on foliage on the short spurs and water sprouts near the trunks of the trees treated with the mists. Counts made on the samples, which were taken from the tree periphery, were low. This condition was not apparent on the trees treated with the conventional sprayer. At the second count, on August 8, the innermost leaves of the misted trees were severely bronzed. The mites had migrated toward the periphery of the tree and began to show up in the leaf counts while the conventionally sprayed trees still maintained a rather low population. By the September 9 count, a heavy mite population was found throughout all the treated trees, including those sprayed with the conventional equipment. The check trees, which had built up a tremendous population in August, were partially defoliated and the mite population had dropped to a very low level.

It is evident, in this particular case, that the mist sprays were not as effective in reaching the mite eggs partially sheltered by the rough bark on the trunks of the trees as was the conventional spray. This indicates that, under certain conditions of rough bark or where heavy insect populations are located on the trunks and scaffold limbs, more effort must be directed toward covering those parts of the trees with the mists. That excellent control of the mites was obtained in the other parts of the tree is shown by the kill of the overwintering eggs and the low populations in the outer parts of the tree on July 11.

SUMMARY.—Seven experiments carried on in six different apple orchards during 1946 and 1947 produced evidence to indicate that the application of dormant oil emulsions in the form of mists may be an efficient and economical method of making such treatments. The amount of oil deposited per unit of bark surface for any given size of tree was found to be correlated with the amount of actual oil applied rather than with the concentration of oil in the mist. The most effective and efficient concentration of oil used was the 25 per cent emulsion. The undiluted oil tended to deposit heavily on nearby limbs and caused injury to the buds in that area of the tree. Oil concentrations above 25 per cent were too viscous to handle satisfactorily in the equipment used, while concentrations below this level added bulk and weight to the emulsion without contributing any measurable advantage.

Compared to conventional sprays the mist applications required one-third to one-half the amount of actual oil per tree to produce an equivalent oil deposit. In one case where there was a heavy population of red mite eggs on the rough bark of the tree trunks some difficulty was experienced in obtaining an effective oil deposit on these eggs. However, where oil deposits were comparable the red mite control was similar whether the material was applied with a high pressure sprayer or in the form of a mist.

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Oils in Dormant Sprays to Control European Fruit Lecanium and Cottony Peach Scale[1,2]

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Dormant or semi-dormant applications of petroleum oils, at 3 per cent concentration, are employed commonly in New York plum, prune and quince plantings to control occasional outbreaks of the European fruit lecanium (Lecanium corni Bouche). Harmon (1927) found similar sprays, at 4 per cent strength, effective against the cottony peach scale (Pulvinaria amygdali Ckll.). A recent heavy infestation of the former in a large quince orchard provided an opportunity to test the efficiency of certain oils against this common lecanium. In 1946, in local peach-growing areas in Western New York, the cottony scale became commercially important for the first time since the period 1925–28. Many growers faced with misgivings and considerable reluctance the necessity of dormant applications of oil sprays to peach trees. Unfortunately, the earlier outbreak of cottony scale coincided with a period when trees in many New York peach orchards were injured severely or even killed outright. Felt (1928) referring to statements made by Professor S. W. Harmon, noted that the injury followed two severe winters when thousands of peach trees were killed or seriously injured. The results from applications of oil sprays to weakened trees or from the use of a combination of oil and copper sulphate solution by a number of growers made a lasting impression upon orchardists and professional workers alike. This situation, together with recent developments in studies of petroleum oils as insecticides, made it desirable to examine again the problem of cottony scale control with dormant applications of oil sprays. This decision provided an opportunity also for additional studies on the effect upon peach trees of petroleum oils and oil-fungicide combinations.

Petroleum oils have long been used extensively against the several stages of scale insects. Only recently, however, has it been demonstrated that differences in the structural composition and other properties of oils are correlated with their efficiency as insecticides. Pearce *et al.* (1942) and Chapman *et al.* (1944) have shown that paraffinic-type oils are more efficient as killing agents than are those classed as napthenic. Among others, eggs of the fruit tree leafroller and winter forms of the San Jose scale were used by these investigators to test the efficiency of various types of oils generally available for dormant spraying. Two of the products chosen for the experiments discussed herein, are representative of distinct types of petroleum oils; that designated by A3 (Table 1) having the characteristics associated with a paraffinic base whereas the properties listed for oil D1 indicate its napthenic character. Oil A1 is an intermediate type.

Table 1.—Composition of oils tested.

	Oil Number		
	D1	A1	A3
Saybolt universal viscosity at 100° F.	120.9	150.6	100.9
Gravity API-60° F.	21.8	27.8	34.2
Density $d_{4°}^{20°}$	.9189	.8842	.8502
Kinematic Viscosity Index (ASTM)	−4	63	115
Aniline point, ° C.	67.0	82.8	104.4
Unsulfonated residue (ASTM) per cent (approx.)	70–75	75–80	90–92

Conventional power spraying equipment was used in these investigations to apply the oil and oil-fungicide combinations under typical dormant conditions. Buds had begun to swell but no green tissue was visible. Owing to winds of varying velocity and direction some overspraying was done to assure complete coverage. Often it was necessary to employ a coarse, driving spray rather than a finer fog-like application which would have been preferable, especially from the standpoint of plant injury. Emulsification was accomplished just prior to spraying by the use of 2 ounces of blood albumin to each 100 gallons of diluted spray except when the treatment included bordeaux mixture. Because Chapman *et al.* (1941) have demonstrated a correlation between

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[1] Journal Paper No. 727, New York State Agricultural Experiment Station, Geneva, N. Y., November 26, 1947.

[2] The authors wish to express their appreciation to Dr. G. W. Pearce and Dr. P. J. Chapman who cooperated in the selection of oils and determination of oil deposits.

[3] Now Extension Entomologist, Univ. of Massachusetts, Amherst.

the quantity of oil deposited on apple bark and the insecticidal value of the treatment, oil deposit data are included in this report.

RESULTS—EUROPEAN FRUIT LECANIUM.—Under New York conditions this coccid suffers a high winter mortality. And since the dead larvae are dislodged easily from the bark, the effectiveness of the several treatments could not be measured by counts of living and dead scales. Fortunately the number of trees treated with each material and the uniformity of the infestation helped to overcome this difficulty. Counts of living scale were made on two series of 6- and 10-inch sections of smaller limbs and branches totaling about 43 linear feet for each treatment and the check. These data, as assembled in table 2, present evidence that, at like concentrations, paraffinic oils are superior to a naphthenic type for the control of this lecanium. In general the increased deposits recorded in this test for oils of the paraffinic types confuse the relationship between oil type, deposit and control efficiency. Attention is directed, however to the control obtained with oils D1 and A1 at 1.0 per cent and with oils D1 at 1.0 per cent and A3 at 0.5 per cent. In these cases, where deposits are comparable, the superiority of the paraffinic oil is quite apparent.

Table 2.—Efficiency of three types of oils in dormant sprays against European fruit lecanium on quince.

Oil Code Number	Per Cent Oil in Spray[1]	Mg. Oil Deposited per Sq. In. Bark Surface	Number of Living Scales per Linear Foot of Limb[2]	Control Efficiency Per Cent
D1	0.25	0.02 (?)	20.4	36.4
D1	0.5	0.10	15.9	50.4
D1	1.0	0.28	11.5	64.1
D1	2.0	0.64	2.3	92.8
A1	0.25	0.07	18.0	43.9
A1	0.5	0.13	13.2	58.8
A1	1.0	0.33	4.5	85.9
A1	2.0	0.82	1.7	94.7
A3	0.25	0.16	9.4	70.7
A3	0.5	0.20	7.1	77.8
A3	1.0	0.56	2.5	92.2
A3	2.0	0.55[3]	0.6	98.1
Control	—	—	32.1	—

[1] Emulsified with 2 oz. actual blood albumin to each 100 gallons.
[2] Based upon examination of two series of 6- and 10-inch sections of limbs totaling about 43 linear feet in each treatment and the check.
[3] Drops of spray material not thoroughly dried down when sample collected; many shaken off in handling.

Table 3.—Efficiency of three types of oils applied in dormant sprays to cottony peach scale.

Oil Code Number	Per Cent Oil in Spray[1]	Mg. Oil Deposited per Sq. In. Bark Surface	Number Scales Examined	Per Cent Alive	Control Efficiency Per Cent
D1	0.5	0.46	1301	52.7	7.6
D1	1.0	0.68	1128	45.9	19.5
D1	2.0	0.77	1099	41.1	27.9
D1	3.0	2.15	959	12.0	64.3
A1	1.0	0.80	999	37.7	33.9
A1	2.0	1.39	765	13.5	76.3
A1	3.0	2.34	1303	2.5	95.6
A3	0.5	0.15	1587	53.7	5.8
A3	1.0	0.45	758	44.9	21.2
A3	2.0	0.86	1398	11.9	79.1
A3	3.0	1.46	1048	2.8	95.1
Control	—	—	1050	57.0	—

[1] Emulsified in tank with 2 oz. actual blood albumin for each 100 gallons.

COTTONY PEACH SCALE.—Unlike the previous species most individuals of the cottony scale remain attached to the bark long after they have died from natural causes or the effects of an oil spray. Counts of living and dead scales found on 2- to 5-year-old wood from each treatment and the check are summarized in tables 3 and 4. When the data in tables 2 and 3 are compared it is apparent, at once, that overwintering forms of the cottony scale are less susceptible to dormant oil sprays irrespective of the type of oil employed. However, a study of the data in table 3

Table 4.—Results obtained with oil alone, oil plus a dinitro compound and oil emulsified with bordeaux mixture.

Amount of Oil, Emulsifier and Other Material per 100 Gallons	Mg. Oil Deposited per Sq. In. Bark Surface	Number Scales Examined	Control Efficiency Per Cent
1% Oil A1, blood albumin 2 oz.	0.80	999	33.9
1% Oil A1, bl. alb. 2 oz., DNOC 19.8 oz.	0.93	1214	74.0
2% Oil A1, blood albumin 2 oz.	1.39	765	76.3
2% Oil A1, 5-5 bordeaux mixture	1.03	1194	43.3
4% Oil A1, 5-5 bordeaux mixture	1.8	1042	64.0

will show unaltered the relationship between paraffinicity and control efficiency. The superiority of the paraffinic oils is well demonstrated by comparisons between treatments for which the deposits were closely parallel; D1 at 0.5 per cent and A3 at 1.0 per cent or oils D1 and A3 at 2.0 per cent are examples. At the 3.0 per cent concentration, relatively heavy deposits of the napthenic and intermediate types of oil gave controls lower or equal to those recorded for a lighter deposit of oil A3.

OIL-FUNGICIDE COMBINATIONS.—In one series of treatments on cottony peach scale 2 pounds of a commercial dinitro powder (40 per cent 4,6 dinitro-o-cresol) were combined with A1 oil at 1, 2 and 4 per cent strengths emulsified in the usual manner. Results were taken from the one per cent treatment only (Table 4). It is quite evident that in this test the effectiveness of the oil was increased greatly by the addition of the dinitro compound. The effect of this combination upon the tree will be discussed in a later section.

Bordeaux mixture (2-4-100) is commonly employed as the emulsifying agent in the preparation of oil sprays. Porter & Sazama (1930), reported studies on the influence of bordeaux mixture on the efficiency of oil emulsions in dormant sprays for the control of San Jose scale. They concluded that the addition of 4-6-100 to 8-12-100 bordeaux mixture reduced the efficiency of the oil in concentrations up to 1.5 per cent. One treatment listed by Harmon (1927) included a 4 per cent oil with 6-6-100 bordeaux mixture; the results obtained indicated a reduced efficiency.

In these experiments, a 5-5-100 bordeaux mixture was combined with A1 oil at 2 and 4 per cent concentrations using the bordeaux as the emulsifying agent. The data obtained, though limited (Table 4), show a definite decrease in the kill of the cottony scale where this combination was used.

EFFECT OF TREATMENTS ON TREES.—Studies made recently on the effect of dormant oil sprays on apple and peach trees showed that the application of oil sprays had marked retarding effects on the respiratory activity of sprayed twigs (Oberle *et al.*, 1944). Similar studies were therefore made on twigs on Elberta peach trees receiving some of the spray treatments listed in tables 3 and 4 and certain other applications. The method used to measure the respiration of the peach twigs was the one described by Oberle *et al.* (1944). Respiration trials were conducted on material collected 6 days, 11 days, and 19 days after spraying or on April 23, April 28 and May 7.

Table 5.—Respiratory activity of Elberta peach twigs sprayed with oil in combination with other materials April 17, 1947.

AMOUNT OF OIL, EMULSIFIER AND OTHER MATERIALS PER 100 GALLONS	MG. OIL DEPOSITED PER SQ. IN. BARK SURFACE	PER CENT CHANGE IN RESPIRATORY ACTIVITY		
		Apr. 23	Apr. 28	May 7
2% Oil A1, emulsified with a 5-5 bordeaux mixt.	1.03	+ 1.1	−1.8	−10.6
4% Oil A1, emulsified with a 5-5 bordeaux mixt.	1.80	+11.3	−0.3	− 8.1
2% Oil A1, bl. alb. 2 oz., DNOC 12.8 oz.	1.32	+29.4	+9.1	−23.1
4% Oil A1, bl. alb. 2 oz., DNOC 12.8 oz.	2.22	+29.5	+0.5	−28.9
Control[1]	—	5.39	5.92	6.87

[1] Mgs. CO_2 evolved per gram of twig during 16 hour period.

Table 5 presents the data from this study. These data show that all of the treatments studied caused increases in the rates of respiration of the twigs still measurable 6 days after spraying; especially sharp increases being recorded for the oil-dinitro combinations.

Five days later the bordeaux-oil sprayed twigs had decreased in the rates of respiration to slightly lower than the check twigs. Twigs receiving the oil-plus-dinitro sprays were still respiring more actively than the checks. Nineteen days after treatment all sprayed trees showed rates of respiration which were markedly lower than those of the check trees. The oil-plus-dinitro sprays caused especially great decreases in respiratory activity.

Visual study, on May 7, of the plots

receiving the various treatments showed that all of the sprayed trees were somewhat retarded in development of buds as compared to the check trees. On May 26 the trees receiving the bordeaux-oil sprays were only slightly retarded as compared to the check trees but the plots receiving the oil-plus-dinitro material showed retardation effects and bud injury as well. A high proportion of the lateral buds, including both fruit and leaf buds, showed unmistakable evidence of injury. Many were already dead and dropped off when touched. Others were still alive but when sectioned were found to have the growing point dead or severely injured. Those which did start growth on these trees were mostly terminal buds or buds near the terminals. These buds probably retained lighter deposits of the spray materials than did those nearer the bases of the twigs. This distribution of new growth gave a peculiar appearance to the trees which has been called "mule tailing" by growers. This condition was still in evidence at midsummer though somewhat masked by the vigorous new shoots produced near the terminals of the twigs. Very few fruits set on the trees receiving the oil-dinitro combinations.

Similar studies made on twigs from Elberta peach trees sprayed while dormant with each of the three types of oils at concentrations up to 4 per cent showed no consistent respiratory response to the treatments. Other than a slight retardation in development associated with the heavier dosages no effect attributable to the oils was observed on these trees.

SUMMARY.—Three types of petroleum oils, emulsified with blood albumin, were used in dormant sprays directed against the European fruit lecanium on quince and the cottony peach scale on peach. Oils having characteristics associated with greater paraffinicity were found more effective against both species than the naphthenic type. Paraffinic oils, at 2 per cent, gave commercial control of the lecanium scale; a 3 per cent oil was required to control the cottony scale.

Against the latter, the effectiveness of oil sprays was increased by the addition of a dinitro compound. Marked increases in the rate of respiration of twigs treated thus were followed by similar decreases due to the injuring or killing of buds.

Emulsification with a 5-5-100 bordeaux mixture greatly decreased the insecticidal efficiency of the oil tested at both 2 and 4 per cent concentrations. No permanent injury to the trees followed the use of this combination although changes in respiratory rates and retardation effects were noted.

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H. C. HUCKETT IN EUROPE

Dr. H. C. Huckett of Riverhead, Long Island, a member of the staff of the New York State Agricultural Experiment Station of Geneva, is spending a six-months sabbatical leave in northern Europe. Mr. Huckett plans to devote some time to studies of Diptera of Northern Europe and to attend the International Congress of Entomology in Stockholm in August.

The Toxicology of 4, 6 Dinitro-o-cresol as an Aphid Ovicide[1,2]

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In areas where winter temperatures fall appreciably below freezing most species of aphids overwinter in the egg stage on a woody host. Advantage may be taken of this fact to control certain economic forms through the use of an ovicide. Such treatments are now restricted, generally, to deciduous fruit trees and shrubs and with these to applications in the full dormant period owing to the caustic nature of products found effective for this purpose. The standard aphid ovicide employed at present is 4, 6 dinitro-o-cresol. An ovicidal treatment will prove most valuable against migratory species

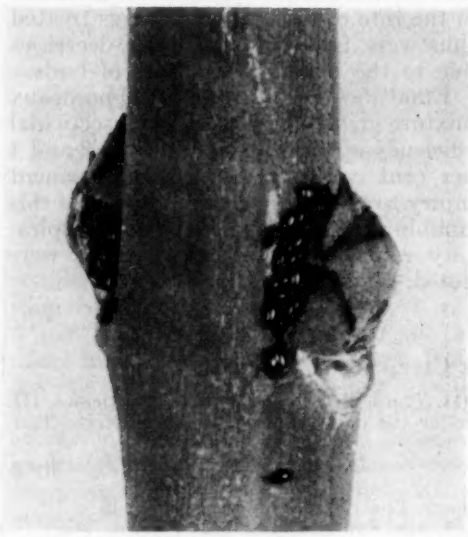

Fig. 1.—Eggs of *Aphis fabae* Scop. on *Euonymus europaeus* L. (enlarged 6X)

where protection is sought for the winter host.

Dinitro-o-cresol received earliest attention from the European dye industry. Although it apparently never found any large use as a dye, it became sufficiently well known to have been named Victoria Yellow. Pastac (1937) reports its use in 1882 as a coloring agent for butter, a practice later abandoned when the toxic nature of the material was learned.

This chemical was first used as an insecticide more than 55 years ago. The potassium salt combined with soap was offered for sale in Germany prior to 1892 under the name of *Antinonnine* (Bourcart 1913). Lodeman (1893) conducted some limited field trials with *Antinonnine* in New York in 1893. He found it highly toxic to plant foliage and ineffective against "the common green plant louse" on quince. Gimingham *et al.* (1926) were the first to show the value of dinitro-o-cresol as an aphid ovicide.

In this country, modern interest in the nitro derivatives of phenolic compounds for insecticides dates back to about 1936 (Dutton). At first considerable interest was shown in dinitro-petroleum oil combinations. The use of this has now greatly lessened owing to the tree injury hazards involved. Where both dinitro and oil are needed, growers in New York are advised to use them in separate treatments, the dinitro in the dormant period and the oil in the "green-tip" or "delayed dormant" bud stage. Weathering is depended upon to remove dinitro residues between sprayings. The present study is restricted to dinitro products used alone in water.

Dinitro-o-cresol is now available commercially in the form of a salt, usually the sodium salt, and as the acid. Both are advised at the same dinitro-o-cresol strength which, for the control of aphids in New York, is 9.6 ounces in 100 gallons water.

The Problem.—It can be said that the use of dinitro-o-cresol for aphid control in orchard spray programs has now been reduced to a fairly satisfactory practice. However, a number of fundamental questions have remained unanswered. These include: What is the minimum quantity of toxicant required to kill aphid eggs? How do various forms of the toxicant compare in efficiency? What effect does water hardness have on performance? How do fall applied treatments compare with spring applications? How much, if anything, do wetting agents contribute to control efficiency? The present

Eastern Branch Program.

[1] Journal Paper No. 739, New York State Agricultural Experiment Station, Geneva, New York, December 18, 1947.

[2] This investigation has been aided by a grant from the Dow Chemical Co., Midland, Michigan.

study was undertaken in 1944 and has been continued during each succeeding year in an attempt to supply this lacking information.

During the course of this work observations have been made on the eggs (Fig. 1) of more than 30 species of aphids[3] while data on the response of aphid eggs to dinitro-o-cresol have been obtained on 22 species. A list of these latter together with the host species involved is given in table 1. (Omissions from this list include several economic species, notably the rosy apple aphid, *Anuraphis roseus* Baker, and the black cherry aphid, *Myzus cerasi* (F.). Sexual forms of these two species and therefore their eggs, were virtually nonexistent locally during the period 1944 to 1947). The purpose behind this effort was to learn whether eggs of various species differed in susceptibility to dinitro-o-cresol and, secondly, if so attempt to establish the maximum and minimum quantities of the toxicant required to kill aphid eggs generally.

The writers, in common with all others who have attempted to use aphid eggs as test subjects, have been impressed with the difficulties in obtaining precise information on their response to insecticidal treatment. Perhaps this accounts for the dearth of published data based directly on the eggs.

One of the more serious complications is the varied hatchability of the eggs, presumably due to variations in fertility. What appear to be healthy eggs several weeks before hatching time may show an extreme range from no hatch to almost complete hatch. A case in point is our 4 years of experience with eggs of the apple aphid, *Aphis pomi* De Geer. In 1945 and 1947 series of test lots involving *A. pomi* eggs had to be discarded owing to the occurrence of either no hatch in controls or variations ranging from zero to an occasional lot showing a normal hatching rate. Fortunately, many common species are more dependable than this. It illustrates further why some economic forms do not make the most satisfactory test subjects in a study such as the present.

Some idea of hatching rate and variations within a series may be gained from data given in table 2. A hatch falling between about 35 and 65 per cent in controls may be considered "normal" in our experience. The hatching rate may vary between aphid species, from year to year with the same species, for the same species and year between eggs from the same host species or variety growing under different environmental conditions, and even between shoot and normal wood growth on

Table 1.—Aphid species studied, plant host, hatching periods of eggs and tentative susceptibility rating to dinitro-o-cresol.

APHID SPECIES	HOST INVOLVED IN STUDY	TIME OF HATCH	SUSCEPTIBILITY RATING
Aphis fabae Scop. (bean aphid)	*Euonymus europaea* L.	early	high
Capitophorus braggii (Gill.)[1]	*Eleagnus* spp. (Russian olive)	early	high
Rhopalosiphum prunifoliae (Fitch) (apple grain aphid)	*Malus pumila* Mill. (apple)	early	high
Myzus persicae (Sulz.) (green peach aphid)[1]	*Prunus Persica* Batsch. (peach)	early	high
Hyalopterus arundinis (F) (mealy plum aphid)	*Prunus domestica* L. (plum)	early	high
Amphorophora sonchi (Oestl.)[1]	*Ribes* spp. (ornamental currant)	early	high[2]
Rhopalosiphum conii David[1]	*Lonicera tartarica* L. (Tartarian honeysuckle)	early	not det.
Periphyllus lyropictus (Kessler)[1]	*Acer platanoides* L. (Norway maple)	early	high
Anuraphis viburnicola (Gill.)[1]	*Viburnum opulus* & *V. opulus sterile*	early	high
Clarigerus salicis (L.) and *C. smithiae* (Mon.)[1]	*Salix* spp. (willow)	interm.	not det.
Aphis spiraecola Patch (Spirea aphid)	*Spirea Vanhouttei*	interm.	interm.
Aphis pomi De Geer (apple aphid)	*Malus pumila* Mill. (apple)	interm.	interm.
Aphis abbreviata Patch (buckthorn aphid)[1]	*Rhamnus cathartica* L. (buckthorn)	interm.	interm.
Cinara strobi (Fitch)[1]	*Pinus strobus* L. (white pine)	interm.	interm.[2]
Myzocallis alhambra David[1]	*Quercus bicolor* Willd. (swamp white oak)	interm.	interm.[2]
Longistigma caryae (Harris)[1]	*Tilia* spp. (linden)	late	interm.[2]
Calaphis betulella Walsh[1]	*Betula papyrifera* Marsh (canoe birch)	late	low
Myzocallis tiliae (L.)[1]	*Tilia* spp. (linden)	late	low
Drepanosiphum platanoides (Schrank)[1]	*Acer pseudoplatanus* L. (sycamore maple)	late	low
Myzocallis coryli Goetz[1]	*Corylus Avellana* L. (filbert)	late	low
Phyllaphis fagi (L.)[1]	*Fagus sylvatica* L. (European beech)	late	low

[1] Determined by P. W. Mason.
[2] Based on limited, one-year data.

[3] Dr. F. L. Gambrell and the senior author are collaborating in a study of the aphids occurring on fruit and ornamental trees and shrubs from the standpoint of their host relationships and general biology. The background gained from this work has been most helpful in the present study. Acknowledgement is made of the invaluable assistance of Dr. P. W. Mason, formerly of the U. S. National Museum, in identifying the various species investigated.

the same tree or shrub. It thus is necessary to replicate test units, to use comparable host wood throughout a test series, and to maintain goodly numbers of controls.

METHODS AND EXPERIMENTS.—Several techniques have been used with apparent success in critical evaluation studies of aphid ovicides. These include methods employed by Peterson (1919), Cutright (1940) and a procedure developed by Kearns & Martin (1936) and modified by Steer (1938) and Tuft (1944). The writers have used Cutright's technique with modifications.

Table 2.—Natural mortality of aphid eggs in typical control series.

Species	Year Observed	Number Replicates	Mean No. Eggs	Mean Per Cent Hatch	Standard Deviation of Hatch
Aphis abbreviata Patch	1947	5	887	25.6	± 4.4
Aphis abbreviata Patch	1947	7	536	52.8	± 6.9
Aphis fabae Scop.	1947	3	1098	56.1	± 5.7
Aphis fabae Scop.	1947	7	877	62.0	± 7.1
Aphis pomi De Geer	1946	9	790	41.4	± 8.9
Aphis pomi De Geer	1944	6	406	72.5	±12.5
Aphis pomi De Geer	1947	9	818	23.7	±10.0
Aphis spiraecola Patch	1947	3	437	70.0	± 4.8
Capitophorus braggii (Gill.)	1946	8	625	55.0	± 6.1
Capitophorus braggii (Gill.)	1945	4	916	49.9	± 8.3
Myzocallis tiliae (L.)	1947	3	806	51.7	±11.8
Phyllaphis fagi L.	1947	9	761	65.2	±11.9
Phyllaphis fagi L.	1947	7	751	68.5	± 7.8
Phyllaphis fagi L.	1947	5	970	89.3	±12.0

This in brief is the method: A count is made of the aphid eggs present on short shoot or twig sections before treatment. These sections are impaled on pins or similar points anchored in a supporting base of cardboard or wood. Before hatching, a sticky barrier is placed around the margin of the base to entrap the aphids as they hatch. A count is then made of the number of aphids hatching which, with the egg count, will provide the essential data for calculating a control efficiency through use of Abbott's equation (1925).

In the present studies, the twig sections were impaled on brads driven through a plywood base (Fig. 2). Brads 0.75 inch long and size No. 19 were used. The dimensions of the base were 0.25×4×5 inches. These impaling blocks, each of which bore 12 twig sections,were the basic experimental units employed throughout the present work. The blocks were transported and held in shallow trays accommodating 16 blocks. These trays were equipped with a frame to support a paper covering placed over the equipment during the hatching period.

Egg counting for spring tests was begun in early March and under local conditions normally has continued into April, especially where late hatching species were being studied. Infested shoots and small diameter limbs were collected in the field shortly before use. As needed, these were cut into sections ranging from about 1 to 5 inches in length, depending upon the intensity of infestation. Counting was done in the laboratory using a binocular microscope. Except for the time required to make the count—usually not over 30 minutes—the eggs were kept under outdoor conditions continuously up until a few days before hatching was due to start, when the blocks were moved into a greenhouse.

Wood sections with fewer than 10 eggs were usually discarded in counting, while an upper limit of about 150 eggs was maintained. The count was based on the number of plump and thus presumably healthy eggs present. Those that were injured, collapsed, or not fully colored were excluded from the count. There was naturally some error in the count. This is believed to have ranged between 1 and 5 per cent, depending upon the ease or difficulty with which various groupings of the eggs could be counted.

The number of eggs present on the 12 wood sections impaled on a block varied

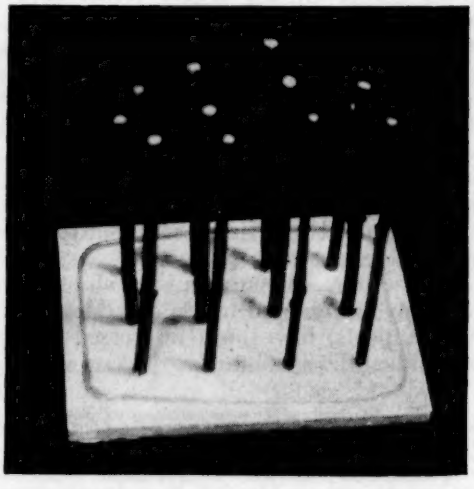

FIG. 2.—Showing infested twig sections mounted on impaling block and *Tanglefoot* barrier.

considerably but typically totaled about 750 eggs. The number of eggs counted for the present studies was as follows: 120,094 in 1944; 194,310 in 1945; 299,733 in 1946 and 815,457 in 1947.

All materials tested were applied in the form of spray. Some series were treated with a standard power orchard sprayer operating at 400 pounds pressure, although the majority were treated under 30 pounds pressure with a compressed air paint spray outfit. The latter work was done in a greenhouse. The impaling blocks were placed on a small electric turn-table during treatment and spraying conditions were standardized. The period of exposure to spray was 40 seconds or until the point of full run-off.

Following treatment, the blocks were held in an outdoor insectary until shortly before hatching was due. Each block was then ringed with a barrier of *Tanglefoot*, placed in a tray and the ensemble enclosed with a paper covering. These covered trays were moved to a greenhouse where egg hatching was forced through to completion. The covering was used to reduce air movement to a minimum. It thus kept debris and insects other than aphids out of the *Tanglefoot* but, more important, kept dead aphids from being blown from one block to another. An apparently normal hatching rate is obtained in the greenhouse *provided the eggs are held under outdoor conditions until shortly before hatching starts*. Sub-freezing temperatures, sleet and high winds occurring during the hatching period may kill some eggs. By following the foregoing procedure, the writers believe the effect of the toxicant alone in killing eggs is shown rather than a possible combination effect of weather and toxicant.

Comparisons of various tests reported were based on a "minimum effective dosage" value or M.E.D. This is defined as the quantity of toxicant required to effect 95 per cent kill and is equivalent to a LD 95 of some workers. In the writers' experience this point on a dosage-mortality curve can be established with reasonable accuracy; further, it has the advantage of having practical as well as technical meaning. Various numbers of replicates have been used in the present studies. The writers have concluded that five replicates should be employed and more would be better. Five replicates were used in all of the important test series run in 1947.

TEST MATERIALS.—Two classes of test materials were employed in the present study: laboratory preparations in which pure chemicals were used alone in distilled water, and commercial dinitro products. The former group consisted of solutions of the acid and of the sodium, calcium, ammonium and magnesium salts. The stock solution of the acid contained 0.034 per cent (3.2 ounces per 100 gallons) of the toxicant, this being about all that would stay in solution at room temperatures. Stock solutions of the salts were made up to .06 per cent (8 ounces per 100 gallons) dinitro-o-cresol. These were prepared by combining chemically equivalent quantities of the acid with the oxide or hydroxide concerned. Standard solutions of the sodium and ammonium hydroxide were used while exact quantities of pure lime and magnesium oxide were weighed out. In using the various stock solutions in this series no wetting agents or other additives were included and dilutions to the spray strengths desired were always made with distilled water.

Two commercial products were employed in this study and may be described as follows:

DN-dry mix No. 2.: A water dispersible powder containing 40 per cent of the toxicant in the form of the acid. The remaining portion consists of inert diluent and wetting agents.[1]

Elgetol: A slurry in which the toxicant occurs as the sodium salt, equivalent to 27.5 ounces dinitro-o-cresol per gallon of product. Also incorporated are one or more wetting agents and so-called "penetrants."[2]

Both commercial products were diluted according to their dinitro-o-cresol content and usually in tap water. Owing to the difficulties of measuring out small representative samples of *Elgetol* a stock solution was prepared by diluting the contents of a gallon lot of the product to 10 gallons.

RESULTS.—Owing to space limitations only samples of data taken during the past 4 years can be given here. Data shown are believed to be representative of the whole.

Since the results of many of the tests

[1] Manufactured by Dow Chemical Co., Midland, Michigan.
[2] Manufactured by Standard Agricultural Chemical Co., Hoboken, New Jersey.

to be reported are based on material that was sprayed with a compressed air sprayer at 30 pounds pressure, it might be of interest at the outset to compare such data with some where treatment was made with a standard orchard sprayer operating at 400 lbs. pressure. Such data are shown in figure 3. It will be seen that results are

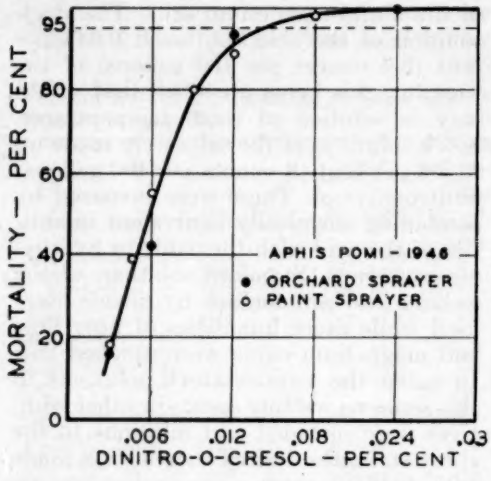

FIG. 3.—Dosage-response curve fitted to combined data obtained with orchard and paint sprayer. Each point represents mean of 5 replicates for former series, 3 for latter.

closely comparable and this is true of other data on hand. Where the orchard sprayer was used, both detached limbs and entire trees and shrubs were sprayed; egg counting was done following treatment.

SPECIFICITY.—Some difference in susceptibility was indicated between *Aphis fabae* and *A. pomi* eggs in the first tests conducted in 1944. Now that work has been done with a score of species, it is clearly evident that the dosage of dinitro-o-cresol required to kill eggs varies considerably between species. This fact appears not to have been appreciated heretofore although Peterson (1923) found eggs of *Rhopalosiphum prunifoliae* more susceptible to strong lime sulfur, *etc.*, than those of *A. pomi*.

Data obtained in the present study suggest that susceptibility for a given species cannot be expressed as an absolute value. It may be expected to vary within a narrow range between egg populations of diverse origins. Just what accounts for these variations is not evident from our records. Lees (1924) has suggested that the "vitality" of the eggs was affected by host vigor with the result that eggs of low vitality, that is, showed a low hatching rate, were more susceptible to insecticidal treatment than eggs from vigorous host plants. This investigator appears to have confused natural mortality with the vitality of viable eggs. Thus it is not evident from the writers' data that after a correction is made for natural mortality *the remaining viable eggs* differ appreciably in susceptibility to insecticides.

Data showing the response of a susceptible, a resistant and an intermediate form are given in figure 4. Results are

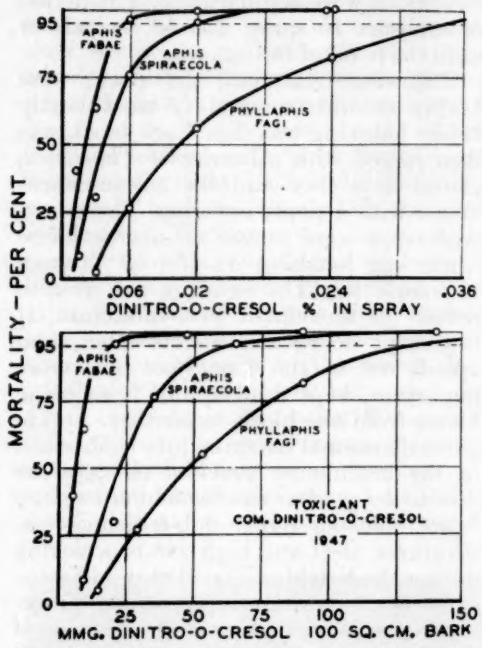

FIG. 4.—Dosage-response curves on three aphid species. Each point represents mean of 3 replicates for *Aphis fabae* and *A. spiraecola* and 5 for *Phyllaphis fagi*.

given both on the basis of toxicant concentration in the spray and quantity deposited[1] on the bark. The deposit data are presented to show that differences evident in the concentration curves are true differences and do not merely reflect a differential deposition rate caused by the varied nature of the surfaces sprayed. It might be assumed in this connection that some precision in testing would be gained by removing the eggs from the plant for treatment. Dierick (1942) has compared

[1] See succeeding article in this number of the JOURNAL.

the response of attached and detached eggs. Higher control efficiencies were obtained in the latter series attributable, so this worker concluded, either to injuring some eggs during removal or to breaking the gelatinous covering which envelops the eggs and serves to cement the eggs to the bark.

A column has been included in table 1 giving the tentative susceptibility rating of species shown here. As already indicated these ratings can be only approximate. Differences between species falling in the two extreme classes are definite and striking; some overlapping in rating may occur, however, between eggs listed as "susceptible" and "intermediate." The approximate dosage of dinitro-o-cresol required to kill 95 per cent of the eggs, or M.E.D., for several species is given in table 3.

Note the correlation shown in table 1 between susceptibility and time of egg hatching in the spring. It will be seen that the earliest hatching species are most readily killed with dinitro-o-cresol while increasingly more toxicant is required for species that hatch later.

Table 3.—Indicated minimum effective dosage of dinitro-o-cresol for several species of aphids under conditions of present study.

Species	M.E.D. of Dinitro-o-cresol (for 95 Per Cent Kill)	
	Spray Concentration Per Cent	Mmg. 100 sq. cm. of Bark
Aphis fabae Scop.	± .006	± 20
Capitophorus braggii (Gill.)	± .006	± 20
Rapolosiphum prunifoliae (Fitch)[1]	± .007	± 30
Aphis spiraecola Patch	± .012	± 60
Aphis pomi De Geer	± .012	± 50
Aphis abbreviata Patch	± .012	± 50
Phyllaphis fagi (L.)	± .03	± 110
Myzocallis tiliae (L.)	± .03	± 110
Drepanosiphum platanoides (Schrank)[1]	± .04	± 200

[1] Based on limited data.

TOXICANT FORM.—Dinitro-o-cresol being an acid readily forms salts of which the writers have studied the sodium, calcium, ammonium and magnesium. These salts all show a moderate degree of solubility in water. The water solubility of the acid, however, is quite low being about 0.028 per cent at 20° C. But this is a quantity sufficient to kill most aphid species, as is shown in figure 4. If the acid form of the toxicant is used in orchard spraying, more than 0.028 per cent would dissolve, of course, owing to the formation of salts with minerals occurring in the spray water.

Aqueous solutions of the acid and of the salts have been compared against eggs of *Aphis pomi*, *A. abbreviate*, *A. fabae*, *Capitophorus braggii* and *Phyllaphis fagi*. Data from some of the tests on *P. fagi* and *A.*

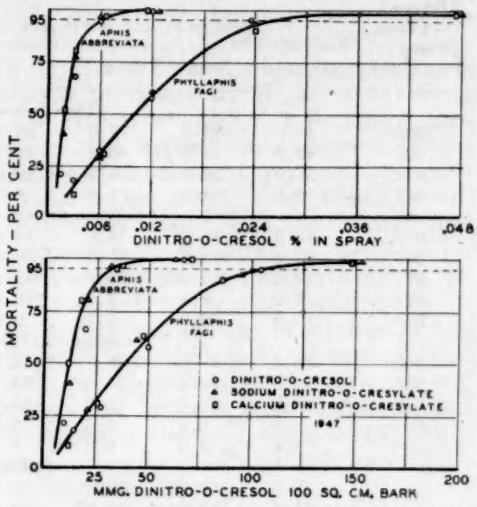

FIG. 5.—Dosage-response curves fitted to combined data obtained on dinitro-o-cresol and its sodium and calcium salts. Each point represents mean of 5 replicates for both species.

abbreviata are given in table 4 and figure 5. Although data are shown only on the performance of the acid and the sodium and calcium salts, little if any difference in performance was found between the forms of the toxicant tested. Some deviations from these results occur in data on hand, but they are not consistent and are attributed to known shortcomings in the testing procedure followed. The writers' findings are in agreement with practical usage. Fruit growers now employ the acid and the sodium salt interchangeably, apparently with equally good results. Dierick (1942), working to a limited extent on aphid eggs but chiefly with eggs of the Mediterranean flour moth, *Ephestia kuhniella* Zell., found aqueous solutions of the acid much more toxic than the salts. These findings differ radically from those of the writers. Since Dr. Dierick's work has obviously been done with care and thoroughness, the only explanation the writers can offer for this disagreement

is that aphid eggs probably differ from *E. kuhniella* eggs in their response to dinitro-o-cresol.

The data in figure 5 suggest that in the salt solutions where dissociation is presumed to be essentially complete, toxicity, is a function of the concentration of cresylate ions present. In the acid system where dissociation is incomplete, the writers conclude the undissociated acid molecules and cresylate ions are equally effective.

Table 4.—Detailed records showing the response of eggs of *Phyllaphis fagi* to dinitro-o-cresol and to its sodium and calcium salts. 1947.

Conc. Dinitro-o-cresol in Spray Per Cent	Percentage Eggs Hatching Replicates						Mmg. Dinitro-o-cresol Deposited per 100 Sq. Cm. of Bark	Control Efficiency Per Cent
	1	2	3	4	5	Ave.		
				Dinitro-o-cresol series				
.003	40.6	45.2	77.9	56.1	48.2	53.6	14	17.7
.006	43.8	41.9	66.5	42.7	43.5	47.7	27	26.8
.012	36.9	42.3	18.4	20.0	23.1	28.2	54	56.8
.024	3.2	1.5	1.6	6.6	3.0	3.2	106	95.1
				Sodium dinitro-o-cresylate series				
.003	28.3	42.0	54.8	44.5	53.6	44.6	12	31.5
.006	64.0	43.1	35.8	30.8	65.9	47.9	21	26.5
.012	19.5	26.9	21.3	31.1	26.5	25.1	43	61.5
.024	2.0	2.4	3.4	10.6	7.3	5.1	96	92.1
.048	0.0	0.0	1.1	0.9	0.5	0.5	154	99.2
				Calcium dinitro-o-cresylate series				
.003	55.9	49.8	62.7	54.1	69.2	58.3	12	10.5
.006	59.3	64.4	32.0	34.1	37.1	45.4	26	30.4
.012	23.9	42.5	13.9	24.8	16.0	24.2	47	62.9
.024	2.9	6.5	9.5	8.8	6.0	6.7	86	89.6
.048	1.6	2.3	0.0	3.5	1.2	1.7	148	97.3
				Control series				
—	58.8	62.2	62.1	70.5	70.3	65.2	—	—
—	61.4	54.3	93.0	54.1	—	—	—	—

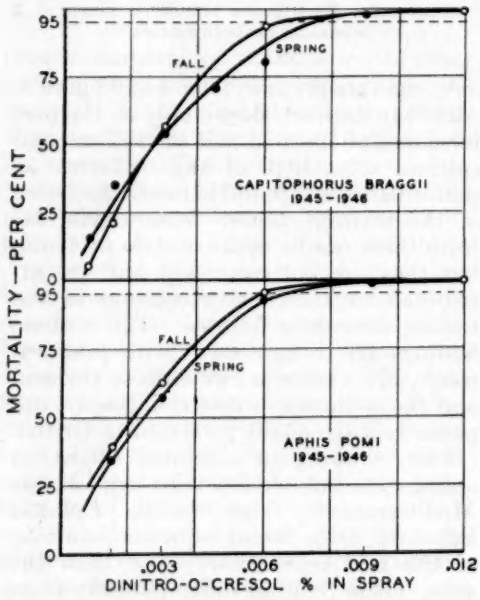

FIG. 6.—Dosage-response curves of fall and spring applied treatments. Each point represents 3 replicates for each species.

FALL *vs.* SPRING TREATMENTS.—Weather conditions permitting, aphid ovicides may be applied at any time from the termination of egg laying in late fall until just before hatching starts in the spring. It is of interest to know, therefore, whether aphid eggs vary in susceptibility to dini-

Table 5.—Response of eggs of *Phyllaphis fagi* (L.) to dinitro-o-cresol applied at various intervals before hatching.

Days Treatment Applied Before Hatch	Toxicant	M.E.D. of Dinitro-o-cresol (for 95 Per Cent Kill)	
		Spray Concentration Per Cent	Mmg. 100 sq. cm. of Bark
	1946 Season		
33	Sodium dinitro-o-cresylate	.03	—
13	Sodium dinitro-o-cresylate	.03	—
13	Commercial dinitro-o-cresol	.026	—
	1947 Season		
41	Commercial dinitro-o-cresol	.023	100–120
27	Commercial dinitro-o-cresol	.03	100–110
19	Commercial dinitro-o-cresol	.03	110–120
19	Sodium dinitro-o-cresylate	.04	110–120

tro-o-cresol at various stages in their embryonic development. The writers are not convinced that data obtained to date on this question answer all points with absolute finality, but the data given in figure 6 and table 5 suggest at least that no large differences exist. This is in agreement with practical experience. Hough (1939) found no differences in results between treatments applied just before hatching and weeks earlier. Twig sections held over winter on impaling blocks in an insectary have not always shown a normal hatching rate. The writers are studying this phase of the problem further in controlled field tests.

DISCUSSION.—The advantage of utilizing what are essentially laboratory procedures to gain information on the basic questions posed earlier in this paper are perhaps self evident. By dealing with known numbers of eggs and controlling conditions of treatment and handling, a degree of testing precision is gained that would be impossible under field conditions. However, it is seldom that data obtained in the laboratory can be applied directly to practical use. But the ultimate goal of work of this nature is in learning how these principles may apply to orchard and field operations. A full interpretation of the findings of the present study in terms of orchard operations will not be attempted at this time since additional evidence is needed to discuss the subject adequately. It is planned to cover this question in a later report.

It may be pointed out that a practical recommendation is not based on the standard employed throughout this study, namely, the minimum quantity of the toxicant that will give control under most favorable conditions. A recommendation should represent the minimum dosage plus a sufficient excess to assure control of the pest in question under the wide range of conditions encountered in orchard spraying operations. Thus while the writers believe a dosage greater than the minimum effective dosage values shown in table 3 should be advised in practical recommendations, some reduction in dosages currently being advised to growers to control these species may be in order. Of interest in this connection are the results published by Gambrell (1942). Dosages of .012 and .0135 per cent (1.6 and 1.8 oz. per 100 gallons) dinitro-o-cresol gave 87.5 per cent and 89.6 per cent control of the viburnum aphid in these field tests.

In the present investigation it was possible to study the action of solutions of dinitro-o-cresol and of several of its salts in the pure state. This has supplied some basic information of interest. In practical field operations, however, even though the acid form of the toxicant may be used, salts will be formed when the product is added to the water in the spray-tank. The extent to which salt formation proceeds will depend on the amount and nature of the minerals present in the particular water source used. Reaction will take place chiefly with the calcium and magnesium compounds in solution for most spray waters in the Northeast.

To assure having a maximum quantity of the toxicant present in solution and in view of the uncertainty of encountering sufficient water hardness in various spray waters, it would seem advantageous when using the acid form to include a small quantity of alkali in the form of lye or hydrated lime.

SUMMARY.—Studies made under controlled conditions on the toxicity of dinitro-o-cresol in aqueous solution to the eggs of 22 species of aphids revealed a difference in susceptibility ranging from a minimum effective dosage (point of 95 per cent kill) of as little as 0.003 per cent for some species to 0.05 per cent or greater for the most resistant species. A minimum effective dosage of 0.012 per cent is indicated for the apple aphid, *Aphis pomi* De Geer.

A correlation was found for various aphid species between susceptibility to dinitro-o-cresol and the relative time of egg hatching. Species whose eggs hatch early proved most readily killed, while increasingly more toxicant was required for later hatching forms.

Solutions of the acid and of its sodium, calcium, ammonium and magnesium salts were found to be equally effective at the same dinitro-o-cresol strength.

Little if any difference in susceptibility to the toxicant was detected in aphid eggs at various stages of embryonic development.

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Potato Tuberworm Control in Virginia

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The potato tuberworm, *Gnorimoschema operculella* (Zell.) was first reported on field potatoes in Tidewater, Virginia in 1923 by Spencer & Strong (1925). Since that time this pest has increased to outbreak numbers and has caused considerable damage to potatoes in field and storage, especially during dry seasons.

Efforts at field control of the tuberworm in this area have met with little success (Poos & Peters 1927). Walker & Anderson (1944a) obtained excellent results with methyl bromide on potatoes in storage, but this material is rather difficult and dangerous to use. In view of the need for more desirable control measures, it seemed advisable to test some of the newer insecticides.

TUBERWORM CONTROL ON STORED POTATOES.—Experiments by Walker & Anderson (1944b) showed that a 2 per cent DDT dust was effective in controlling tuberworm injury to seed potatoes in storage. Lloyd (1946) reported promising results with DDT dusts on the tuberworm in Australia.

Eastern Branch Program.

Preliminary laboratory tests were conducted January 10, 1947, using various DDT treatments. In these tests clean potatoes placed in DDT-treated muslin bags remained free of injury when confined in chambers with tuberworm pupae and adults. All moths were knocked down after a few hours exposure. The same results were obtained where pupae and adults were placed in battery jars covered with DDT-treated cloth. Infested potatoes placed in treated chambers became uninfested as the moths emerged and were killed. All check lots of potatoes became heavily infested.

Further tests, comprising a total of nine treatments replicated three times, were begun March 27, Single lots of ten uniformly small potatoes, bagged or not bagged as indicated in table 1, were added to battery jars. The jars were covered with cheesecloth and 30 test insects introduced into each jar. For this test individual pupae were isolated in small glass vials and the adults sexed upon emergence. Equal numbers of males and females were thus added with a minimum of mortality.

During this experiment the temperature varied from 65° to 75° F. and the relative humidity from 50 to 60 per cent.

Adult mortality counts were taken at the end of 24 hours. One month later the potatoes were examined for tuberworm injury. As may be seen from the results presented in table 1, complete control was obtained in the DDT bag treatments where all moths were killed within 24 hours and all tubers remained uninfested. Failure of the tuberworms to establish themselves when pupae only were added strongly indicates that the spread of an infestation in storage could be checked by such treatment. DDT-treated confetti and paper streamers gave highly significant reductions in tuberworm populations but not complete control. It is interesting to note that all larvae coming in contact with the confetti died.

The DDT-treated bags used in the March 27 test were checked for residual action on October 10. The same methods were employed as in the preceeding experiment except that six replications were made. The results of these residual tests (Table 1) show that all the DDT treated burlap bags still gave complete control after 6.5 months.

TUBERWORM CONTROL IN POTATO FOLIAGE.—In laboratory tests a 50 per cent DDT wettable powder proved very effective in controlling tuberworms in potato foliage. Potted potato plants sprayed with DDT suffered little injury upon exposure to heavy larval populations, whereas the untreated checks were destroyed within two weeks.

DUST TESTS.—Dust tests were conducted on a field of late Sebago potatoes at Back Bay, Virginia. At the time of treatment the degree of infestation was so severe that many of the plants were completely defoliated and large bare areas were visible in the field. All plats were 140 feet long by 24 feet (eight rows) wide and were replicated four times within randomized blocks. The materials were applied with a motor-driven, eight-nozzle tractor-drawn duster having the nozzles adjusted with two per row and discharging under a 25 foot cloth trailer. The treatments were made on September 9, 1947, between 4:00 and 5:15 PM. The temperature ranged from 80° to 79° F., the relative humidity from 64 to 80 per cent, and the wind velocity from 7 to 4 miles per hour. Although the wind was rather gusty it blew down the rows and little drift resulted. A heavy rain occurred about 72 hours after treatment. A second application was made September 19 between 4:30 and 6:00 P.M. during which time the temperature dropped from 84° to 74° F., the relative humidity increased

Table 1.—Effect of DDT treatments on potato tuberworms on stored potatoes.

TREATMENT	TEST 1—MARCH 27		TEST 2—OCTOBER 10	
	Per Cent Kill of Adults in 24 Hours	Tunnels per Tuber after 30 Days	Per Cent Kill of Adults in 24 Hours	Tunnels per Tuber after 30 Days
Potatoes in bags				
1% DDT impregnated burlap bags	100	0	100	0
2.5% DDT impregnated burlap bags	100	0	100	0
5% DDT impregnated burlap bags	Pupae used	0	Pupae used	0
5% DDT impregnated muslin bags[1]	100	0	100	0
Check—untreated burlap bags	10	3.5	10	4.1
Potatoes unbagged				
5% DDT impregnated confetti[2]	93	.4		
5% DDT impregnated streamers[3]	80	1.3		
Sprout Inhibitor[4]	20	2.5		
Check	7	9.5		
Difference required for significance (19 to 1 odds)		.8		

[1] This material treated January 10, 1947, all others treated March 27.
[2] Twenty-four square inches of newspaper confetti per test lot.
[3] Three (0.25×6") newspaper streamers per test lot.
[4] A 2.2 per cent methyl ester of alpha naphthyl acetic acid dust applied at the rate of 1 lb. per 11 bushels of potatoes. Dow Chemical Co.

from 74 to 80 per cent and the wind velocity ranged from 2 to zero miles per hour. Heavy rains began about 36 hours after treating and continued for almost a week. Conditions for tuberworm development remained unfavorable throughout the remainder of the month and during the first 2 weeks of October.

Several methods of taking records were employed. At 24-hour intervals counts were made on the number of dead or dying larvae on the ground around each hill and per foot of row in the depression left by cultivation between rows. A later method consisted of taking 50 leaflets with tunnels from each plat and determining the number of leaflets containing live larvae. A final check was made by selecting 10 hills at random from each plat, counting the number of injured leaflets and then determining the number of infested leaflets. All records were taken on the two center rows of each plat.

The different materials tested, rates of application and results obtained are given in table 2. All treatments resulted in highly significant reductions in tuberworm populations. There were no significant differences between the DDT, and dichlorodiphenyldichloroethane and benzene hexachloride treatments—all giving over 99 per cent reduction in tuberworm populations at the final check. Likewise all treatments resulted in highly significant reductions in leaflets with tunnels, but with no significant differences between the various materials. Injury increased in the check plats until all plants were practically defoliated.

It is interesting to note that within 24 hours after dusting many larvae of all instars had left their tunnels in the treated plats and were lying dead or dying on the ground. This was more pronounced in the benzene hexachloride plats than in the DDT and dichlorodiphenyldichloroethane plats. Few additional larvae appeared on the ground in the benzene hexachloride plats after 48 hours whereas on all other treated plats a steady increase occurred up to 72 hours, at which time a heavy rain precluded further observations.

Table 2.—Results of dusting potatoes for control of the potato tuberworm in foliage at Back Bay, Virginia, September 9, 1947.

Treatment	Pounds per Acre		No. Leaflets with Larvae and Per Cent Reduction Below Check				No. Leaflets with Tunnels and Per Cent Reduction Below Check	
			Per 50 Leaves Sept. 23		Per 10 Hills Oct. 8		Per 10 Hills Oct. 8	
	Sept. 9	Sept. 19	No.	Per Cent	No.	Per Cent	No.	Per Cent
1% DDT-Impregnated[1]	47	42	0	100	.8	99	16	98
2% DDT-Impregnated[1]	42	44	.25	99	.3	99	15	98
2% DDT-Regular	44	45	.5	99	3.8	99	28	97
3% DDT-Impregnated[1]	30	41	.75	98	3.0	99	23	97
5% Dichlorodiphenyl-dichlorethane	45	45	0	100	.8	99	17	98
1% Gamma isomer of benzene hexachloride[2]	44	44	0	100	.3	99	17	98
Check	—	—	36.25	—	548.5	—	822	—
Difference required for significance (19 to 1 odds)			5.1		23.3		23	

[1] 2% *Velsicol AR 60* used as impregnating agent.
[2] Clay used as diluent in benzene hexachloride, pyrophyllite in all other mixtures.

In addition to the Back Bay dust tests observations were made on several commercial plantings which were treated with a 3 per cent DDT dust. The dust was applied at approximately 40 lbs. per acre and excellent control was obtained.

Spray Tests.—A single application of four spray materials was made in the same field of Sebago potatoes at Back Bay. Treatments were made with a 3 gallon compressed air knapsack type sprayer. All plats were single 60 foot rows replicated three times within randomized blocks. The sprays were applied September 11, 1947, between 4:00 and 5:00

P.M. The temperature ranged from 82° to 80° F., the relative humidity from 70 to 78 per cent, and the wind velocity from 3 to 1 miles per hour. The same methods of taking records were employed as in the dust tests. Heavy rains occurred within 36 hours after treatment.

The materials tested, rates of application and results obtained are given in table 3. Observations at the end of 24 hours indicated the same trend as in the dust tests. Twelve-day counts showed that the DDT, dichlorodiphenyldichloroethane and benzene hexachloride gave a highly significant reduction in infested foliage but failed to show a significant difference between treatments. At the end of 27 days benzene hexachloride was significantly less effective than the other materials. The number of leaflets with tunnels was reduced at least 94 per cent in all treatments except the benzene hexachloride which was significantly poorer with only 64 per cent reduction.

Table 3.—Results of spraying potatoes for control of the potato tuberworm in foliage at Back Bay, September 11, 1947.

Treatment[1]	No. Larvae on Ground	No. Leaflets with Larvae		No. Leaflets with Tunnels and Per Cent Reduction Below Check	
	Per 10 Hills	Per 50 Leaves	Per 10 Hills	Per 10 Hills	
	After 24 Hrs.	Sept. 23	Oct. 8	Oct. 8	
				Number	Per Cent
50% DDT W.P.	54	0	2	15	96
50% Dichlorodiphenyldichloroethane W.P.	48	.3	1	16	96
7.5% γ benzene hexachloride W.P.	137	0	88	151	64
25% DDT-oil emulsion	62	0	4	25	94
Untreated check	.3	35.3	222	415	—
Difference required for significance (19 to 1 odds)	31	1.5	30	38	

[1] All wettable powders used at concentration of 2 lbs. per 100 gallons of water, 25% DDT-oil emulsion at 1 quart per 100 gallons of water. All treatments applied at 125 gallons per acre.

In field tests excellent control of the potato tuberworm in foliage was obtained by two applications of 1, 2 and 3 per cent DDT impregnated dusts, 2 per cent regular DDT dust, 5 per cent DDD dust and a 1 per cent gamma isomer of benzene hexachloride dust. These materials reduced tuberworm populations in all the treated areas over 99 per cent and resulted in a decrease of 97 to 98 per cent in the number of leaflets with tunnels.

Single spray applications of a 50 per cent DDT wettable powder, a 50 per cent DDD wettable powder and a 25 per cent DDT-oil emulsion also gave a high degree of control. A wettable benzene hexachloride powder containing 7.5 per cent gamma isomer was significantly less effective than the other materials.

SUMMARY.—Complete tuberworm control was obtained on potatoes stored in burlap bags dipped in xylene solutions containing from 1 to 5 per cent DDT. Treated bags were still giving control 10 months after dipping. Confetti and paper streamers treated with 5 per cent DDT gave significant reductions in tuberworm populations but not complete control.

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Control of the Two-Spotted Spider Mite on Lima Beans, on Long Island

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Considerable attention has recently been focussed on the reports concerning the value of several synthetic organic compounds as acaricides under field and greenhouse conditions (Boyce *et al.* 1939; Kearns *et al.* 1945; Blauvelt 1945; Haring 1946; Ludvik & Decker 1947; Roark 1947). With the release of this information it seemed desirable that preliminary trials should be made under local conditions to ascertain whether any such compounds could be used advantageously on lima beans for control of the two-spotted spider mite, *Tetranychus bimaculatus* Harvey.

For several successive seasons field tests have been made on Long Island for the purpose of comparing the merits of mixtures containing elemental sulfur and those containing dinitro compounds (dinitro-ortho-cyclohexyl phenol and its amine salt) for control of the spider mite without having reached any conclusive results or recommendations. This condition of affairs has been due largely to the variability of the results from season to season, particularly in relation to the weather and growing conditions. It was also evident, largely during war years, that any treatment that might be effective against the spider mite would be considered more useful if it was also capable of providing a greater degree of protection against other foliage destroyer, such as the bean aphid, Mexican bean beetle, green cloverworm, corn earworm and European corn borer. During the past season, therefore, the number of compounds tested was increased to include a few that might possibly be found to be effective against mites and insects on lima beans, and which might prove to possess a wider margin of safety in relation to plant tolerance.

The materials selected for trial were as follows: Elemental sulfur, in a wettable powder for spraying, or conditioned and diluted with talc for dusting; dinitro-talc dusts, with or without sulfur, the former containing 50 per cent sulfur and 1 per cent dinitro-o-cyclohexyl phenol, the latter 1 per cent and 0.5 per cent of the dinitro compound; also talc dusts containing 1.7 per cent and 1 per cent of the dicyclo-hexyl amine salt of the dinitro compound, and a powder containing 20 per cent of the amine salt for sprays;[1] azobenzene-talc dusts possessing 10 and 5 per cent of the toxicant, and a wettable powder of 48 per cent azobenzene strength for sprays;[2] a powder containing 25 per cent of the gamma isomer of benzene hexachloride;[3] a chlorinated camphene, in a wettable powder of 25 per cent toxicant content and in a water miscible solution of 50 per cent strength for sprays, also in a powder analysing 11.8 per cent toxicant for dilution into dusts;[4] the chlorinated hydrocarbon, chlordane, in a wettable powder containing 50 per cent of the toxicant for sprays or dusts;[1] hexaethyl tetraphosphate;[5] and talc dusts containing 1 and 0.5 per cent of parathion.[6]

For the purpose of improving the wetting properties and adherence of certain sprays skim-milk powder was added to the dinitro powder at the rate of 2 pounds per 100 gallons of water; a soybean powder[7] to wettable powders containing chlorinated camphene, chlordane and azobenzene at the same rate; a commercial emulsifier[8] to powder suspensions of the gamma isomer of benzene hexachloride and to hexaethyl tetraphosphate at the rate of 0.5 pint per 100 gallons of water. In cases where it was necessary to dilute powders for dusting purposes a diatomaceous earth was included in the formula at the rate of 5 per cent by weight to improve the dusting qualities of the mixture, the remainder of the diluent being composed of talc.

The strengths of finished dusts in terms of active ingredients and the amounts of spray powders or liquids per 100 gallons

[1] Products of Dow Chemical Company, Midland, Mich.
[2] Product of Allied Chemical and Dye Corporation, Buffalo, N. Y.
[3] Product of California Spray-Chemical Corporation, Elizabeth, N. J.
[4] *Toxaphene*, a product of Hercules Powder Company, Wilmington, Delaware.
[5] Product of Monsanto Chemical Company, St. Louis, Missouri.
[6] Product of American Cyanamid Company, New York.
[7] *Soyspra A.*
[8] *Emulsifier B 1956 Spreader.*

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Table 1.—Prevalence of the bean aphid and Mexican bean beetle in plots following dust applications for control of two-spotted spider mite as denoted respectively by extent of bloom infestation and foliage injury.

Dust Treatment, Per Cent Strength of Active Ingredients	Per Cent of Flower Stalks Infested by Bean Aphid	Extent of Foliage Injury by Mexican Bean Beetle	
		Grades and Score (max. 40)	
Sulfur 50%	36.0	slight	13
Sulfur 50%, dinitro-o-cyclohexyl phenol 1%	19.5	trace-slight	9
Dinitro-o-cyclohexyl phenol 1%	14.5	slight	13
Dinitro-o-cyclohexyl phenol 0.5%	14.0	slight	14
Amine salt of dinitro-o-cyclohexyl phenol 1.7%	20.0	slight-moderate	18
Amine salt of dinitro-o-cyclohexyl phenol 1%	17.0	slight-moderate	19
Chlorinated camphene 5%	4.0	none-trace-slight	9
Chlorinated camphene 3%	10.0	slight-moderate	17
Chlordane 3%	7.0	slight	16
Chlordane 2%	8.5	slight	14
Azobenzene 10%	19.5	slight-moderate	16½
Azobenzene 5%	13.0	slight-moderate	17½
Parathion 1%	0.5	none-trace	2
Parathion 0.5%	0	none-trace	3
Checks	16.0	slight-moderate	17½

of water are given in tables 3 and 4.

These sprays and dusts were applied four times during the period July 2 to August 12 for control of the spider mite, intervals between applications averaging about 13 days. Treatments were made with hand machines at an average rate equivalent to 50 to 70 pounds per acre for dusts and 102 to 200 gallons for sprays, according to increased growth of foliage. In addition, all plots were dusted on June 20 and on August 5 with a cube-talc dust of 0.75 per cent rotenone strength for control of the Mexican bean beetle.

The field tests were carried out on the Fordhook variety of bush lima bean, sown on June 2 and harvested August 29 to September 6. The planting consisted of 16 rows divided into 8 tiers, four being reserved for dusts and 4 for sprays. Each tier contained a full series of treatments consisting of single row units, 30 feet in length, and two untreated rows. The plots were arranged systematically and the position of the series was shifted per tier in an attempt to distribute the plots as evenly as possible in the field.

Sources of spider mite infestation were

Table 2.—Prevalence of the bean aphid and Mexican bean beetle in plots following spray applications for control of two-spotted spider mite as denoted respectively by extent of bloom infestation and foliage injury.

Spray Treatment, Amounts per 100 Gallons of Water	Per Cent of Flower Stalks Infested by Bean Aphid	Extent of Foliage Injury by Mexican Bean Beetle	
		Grades and Score (max. 40)	
Sulfur wettable powder 12 lbs.	33.5	slight-moderate	17
Amine salt of dinitro-o-cyclohexyl phenol 20% powder 2 lbs.	13.5	slight	15
Chlorinated camphene 25% wettable powder 4 lbs.	6.5	trace-slight	11
Chlorinated camphene 25% wettable powder 2 lbs.	14.0	slight-moderate	15
Chlorinated camphene 50% solution 1 quart	4.0	trace	8
Chlorinated camphene 50% solution 1 pint	5.0	trace-slight-moderate	14
Chlordane 50% wettable powder 2 lbs.	7.0	slight	16
Chlordane 50% wettable powder 1 lb.	8.0	slight-moderate	21
Gamma benzene hexachloride 25% powder 1 lb.	1.5	slight	15
Gamma benzene hexachloride 25% powder 8 oz.	5.0	slight-moderate	19
Azobenzene 48% wettable powder 4 lbs.	26.5	slight-moderate	20
Azobenzene 48% wettable powder 2 lbs.	12.0	slight-moderate	17
Hexaethyl tetraphosphate 100% 1 pint	0	trace	6
Hexaethyl tetraphosphate 100% 8 oz.	1.5	trace	7
Checks	35.0	slight-moderate	19½

Table 3.—Effectiveness of dust treatments for control of two-spotted spider mite on lima beans as indicated by comparative yields of clean and discolored pods due to mite feeding.

Dust Treatment, Per Cent Strength of Active Ingredients	Weight of Marketable Pods in Pounds per 100 Plants, Graded as to Extent of Mite Injury			Per Cent Gain or Loss in Clean Pods over Checks
	Total	Clean	Discolored	
Sulfur 50%	20.62	13.48	7.14	−15.75
Sulfur 50%, dinitro-o-cyclohexyl phenol 1%	20.84	14.76	6.08	− 7.75
Dinitro-o-cyclohexyl phenol 1%	23.86	19.57	4.29	18.24
Dinitro-o-cyclohexyl phenol 0.5%	23.66	17.81	5.85	10.16
Amine salt of dinitro-o-cyclohexyl phenol 1.7%	23.20	19.24	3.96	16.84
Amine salt of dinitro-o-cyclohexyl phenol 1%	21.88	16.36	5.52	2.20
Chlorinated camphene 5%	24.60	21.04	3.56	23.95
Chlorinated camphene 3%	25.52	20.57	4.95	22.21
Chlordan 3%	25.02	20.97	4.05	23.70
Chlordan 2%	26.10	20.37	5.73	21.45
Azobenzene 10%	30.36	26.68	3.68	40.03
Azobenzene 5%	28.57	26.17	2.40	38.86
Parathion 1%	30.60	28.73	1.87	44.31
Parathion 0.5%	27.24	24.04	3.20	33.44
Checks	23.50	16.00	7.50	

artificially created by placing crocks containing infested bean plants at uniform distances along the borders of the field, these being covered with screened cages for purposes of protection. These cages were set out in the field on June 14, and by July 2 samplings in untreated rows indicated that nearly all plants harbored mites. Foliage infestation gradually increased during July and August, by which time marked differences had developed in the appearance of the foliage in various plots relative to spider mite control. Early it became apparent that the foliage in plots treated with hexaethyl tetraphosphate, parathion and chlorinated camphene was markedly freer from feeding injury than that in plots treated with sulfur or with various dusts of the lower category in toxicant strength. Closer examination indicated that there was a marked decrease in aphid colonies on the flower stalks and in the amount of Mexican bean beetle injury on the foliage in plots treated with the phosphate compounds. This condition is reflected in the data recorded during the first week of August and summarised in tables 1 and 2. In procuring this information the prevalence of aphid infestation was determined by noting the

Table 4.—Effectiveness of spray treatments for control of two-spotted spider mite on lima beans as indicated by comparative yields of clean and discolored pods due to mite feeding.

Spray Treatment, Amounts per 100 Gallons of Water	Weight of Marketable Pods in Pounds per 100 Plants, Graded as to Extent of Mite Injury			Per Cent Gain or Loss in Clean Pods over Checks
	Total	Clean	Discolored	
Sulfur wettable powder 12.5 lbs.	18.86	11.16	7.70	−31.07
Amine salt of dinitro-o-cyclohexyl phenol 20% powder 2 lbs.	23.25	15.92	7.33	− 1.67
Chlorinated camphene 25% wettable powder 4 lbs.	26.76	22.76	4.00	28.87
Chlorinated camphene 25% wettable powder 2 lbs.	24.37	19.56	4.80	17.23
Chlorinated camphene 50% solution 1 quart	27.24	23.96	3.28	32.43
Chlorinated camphene 50% solution 1 pint	23.26	19.39	3.87	16.50
Chlordane 50% wettable powder 2 lbs.	23.64	17.82	5.81	9.15
Chlordane 50% wettable powder 1 lb.	24.00	17.96	6.04	9.85
Gamma benzene hexachloride 25% powder 1 lb.	25.07	19.28	5.79	16.03
Gamma benzene hexachloride 25% powder 8 oz.	23.56	18.78	4.78	13.79
Azobenzene 48% wettable powder 4 lbs.	26.74	21.40	5.34	24.34
Azobenzene 48% wettable powder 2 lbs.	26.44	21.68	4.76	25.32
Hexaethyl tetraphosphate 100% 1 pint	26.76	23.40	3.36	30.81
Hexaethyl tetraphosphate 100% 8 oz.	25.98	21.68	4.30	25.32
Checks	22.69	16.19	6.50	

presence or absence of aphids on 50 flower stalks chosen at random in each plot; the extent of Mexican bean beetle injury to the foliage in each plot was graded according to the following captions, none, trace, slight, moderate, severe, with a scale of points assigned to each category, thus, 0, 1–2, 3–4, 5–7, 8–10, respectively.

The effectiveness of the different treatments in combatting the spider mite was based largely on differences in yield of marketable pods that were considered commercially free of discoloration due to spider mite feeding, and termed "clean." For this purpose all pods in each plot were picked, graded, and weighed, and the plants counted. The yields were finally computed on a 100-plant basis. The data obtained by this method are summarised in table 3 and 4.

The information provided in these tables indicated that the most satisfactory results with dusts were obtained with mixtures containing 1 and 0.5 per cent of parathion plots averaging increases of 44.3 and 33.4 per cent of clean pods over checks and having shown little evidence of aphid and Mexican bean beetle infestation. Plots dusted with mixtures containing 10 and 5 per cent azobenzene averaged increases of 40 and 38.8 per cent clean pods respectively, but they had not been free of considerable evidence of aphid and Mexican bean beetle infestation.

Plots dusted with mixtures containing chlorinated camphene at 5 and 3 per cent strengths and chlordane at 3 and 2 per cent strengths averaged increases ranging from 21.4 to 23.9 per cent clean pods over checks, the data indicating that there was little to choose between the treated plots in this respect. The treatments had manifested a certain degree of merit against the bean aphid, but there were no indications of any appreciable reduction in extent of foliage injury by the Mexican bean beetle except possibly in the case of plots dusted with a mixture containing 5 per cent chlorinated camphene.

Plots dusted with mixtures containing dinitro-o-cyclohexyl phenol and the amine salt of the dinitro compound respectively yielded slightly less marketable pods than other treated plots. However plots dusted with mixtures containing 1 per cent dinitro-o-cyclohexyl phenol and 1.7 per cent the amine salt of the dinitro compound respectively yielded increases of 18.2 and 16.8 per cent over checks in terms of clean pods. There was little evidence to show that the dinitro treatments had had any significant effect on the prevalence of bean aphid and Mexican bean beetle infestations.

In plots dusted with mixtures containing 50 per cent sulfur, with or without the addition of 1 per cent dinitro-o-cyclohexyl phenol, the yields were noticeably reduced, and there was little or no apparent protection afforded the pods from the effects of spider mite feeding. The results in tests with these dusts in recent years have tended to corroborate this observation.

The most promising results with sprays were obtained with mixtures containing respectively 1 pint of hexaethyl tetraphosphate, 1 quart of a 50 per cent solution of chlorinated camphene or 4 pounds of a wettable powder of 25 per cent chlorinated camphene content per 100 gallons of water. The plots averaged gains in terms of clean pods over checks of 30.8, 32.4, 28.8 per cent respectively, and all plots had possessed a minimum of evidence of aphid and Mexican bean beetle infestation.

Plots treated with sprays containing hexaethyl tetraphosphate at the rate of half a pint per 100 gallons of water, or azobenzene (48%) in wettable powder form at 4 and 2 pounds, averaged increases of 25.3, 24.3, and 25.3 per cent respectively in terms of clean pods, but in the case of azobenzene treatments the plots had exhibited an appreciable degree of aphid and Mexican bean beetle infestation.

Smaller increases were obtained in plots treated with suspensions of the gamma isomer of benzene hexachloride and chlordane respectively, and with sprays containing weaker strengths of chlorinated camphene. In the case of chlordane treatments special difficulties were encountered in pumping the spray suspensions out of the tank, which may have had its effect on the results.

Plots sprayed with a suspension of sulfur at the strength of 12.5 pounds of wettable powder per 100 gallons of water yielded less marketable pods than did the checks and a greater amount of discolored pods due to spider mite feeding. No gains were recorded in plots sprayed with a sus-

pension of the amine salt of dinitro-o-cyclohexyl phenol.

During the season of 1947 there were no significant indication of plant injury due to treatment, as had been noticed in previous tests of dusts containing dinitro and azobenzene compounds respectively. The feasibility of using such effective compounds as hexaethyl tetraphosphate, parathion or chlorinated camphene for future commercial purposes seems largely dependent on the outcome of tests dealing with their toxicological properties in relation to the soil and to man.

SUMMARY.—Comparative field tests were made of treatments containing respectively sulfur, dinitro-ortho-cyclohexyl phenol and its amine salt, chlorinated camphene chlordane, gamma isomer of benzene hexachloride, azobenzene, hexaethyl tetraphosphate, and parathion as toxicants for control of the two-spotted spider mite on lima beans. The various mixtures were tested at two strengths in terms of active ingredients and, were applied four times during the period of spider mite infestation. Their effectiveness was recorded in terms of yield of marketable pods commercially free of discoloration due to mite feeding. Observations were also noted concerning their possible value for control of the bean aphid and the Mexican bean beetle.

The data indicated that the most effective treatments for control of the spider mite were those that contained hexaethyl tetraphosphate, parathion or azobenzene, there being in each case only a slight degree of difference in effectiveness between treatments having the higher toxicant strength as compared to those of the lower strength. Chlorinated camphene sprays were also highly effective against the spider mite when applied at the higher toxicant strength. Dusts containing chlorinated camphene at 5 and 3 per cent toxicant strength and chlordane at 3 and 2 percent strength respectively, were about equally effective against the spider mite, and all were slightly less so than dusts containing parathion or azobenzene. The more effective dusts containing the dinitro compound or its amine salt were slightly less effective against the spider mite than dusts containing the chlorinated hydrocarbons. Plots dusted or sprayed with sulfur mixtures were inferior in most respects to untreated plots.

The data also indicated that plots that had been treated with hexaethyl tetraphosphate or parathion for spider mite control exhibited a minimum degree of infestation by bean aphid or Mexican bean beetle as compared to conditions in these respects in other plots. There was also an appreciable reduction in bean aphid infestation in plots treated with mixtures containing chlorinated camphene chlordane and the gamma isomer of benzene hexachloride respectively as compared to check plots, but there were few instances to indicate that any such treatments may have had a significant effect in diminishing the extent of Mexican bean beetle injury, except possibly in the case of chlorinated camphene treatments of the higher toxicant strength. Plots treated with mixtures containing azobenzene, the dinitro compound or its amine salt, or sulfur respect tively, applied for control of the spider mite, invariably exhibited little satisfactory evidence of effectiveness for aphid or Mexican bean beetle control.

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Control of Mites on Apple Trees Sprayed with DDT

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Since reporting on attempts to control mites on apple trees sprayed with DDT (Hough 1946) a number of new compounds have been used. This report summarizes the more important tests made during the past two seasons.

Methods.—All sprays were applied with a power sprayer using 400 pounds pressure. Where DDT was used in the combination with the acaricide for codling moth control, the type of spraying was similar to that employed by the orchardists, that is, the sprays were applied from the outside of the trees, one sprayman on the ground and another in the tower on top of the sprayer. In the single tree tests all of the spraying was done from the ground position, the sprayman first going under the branches and thoroughly covering the foliage from that position then completing the application by going around the tree on the outside. Samples of 100 leaves were selected at random by walking around the tree and placed in moisture-proof cellophane bags which were brought to the laboratory and brushed in a manner described by Henderson & McBurnie (1943).

The leaves were brushed within several minutes to an hour or two from the time of picking. It was learned, however, that samples placed in the refrigerator within an hour of picking could be kept for at least 24 hours without apparently affecting the count. To evaluate the treatments the mite population on the treated trees was compared with the population on nearby check trees and usually from some of the trees to be sprayed at the time of spraying or on the day before the sprays were applied. In the single tree series beginning on August 12 and replicated on four successive days (Table 3) the population on each treated tree was compared to the population found on the sample taken from the same tree immediately before the treatment was applied.

Results of Tests in 1946.—Materials combined with wettable DDT in three cover sprays on Delicious variety included the following at the indicated rate of dilution in 100 gallons of water: 25 per cent wettable azobenzene, 4 pounds; xanthone, 1 pound; 30 per cent wettable hydroxypentamethyl flavan, 4 pounds; disodium ethylene bisdithiocarbamate,[1] 2 quarts; 83 per cent summer oil emulsion, 6 quarts; and triethanolamine salt of dinitro-o-cyclohexylphenol[2], 1.25 pounds. Azobenzene and the disodium compound[1] gave no control and the other materials were either less effective or no more effective than the standard acaricide[2] used by commercial apple growers.

Results of Tests in 1947.—Tables 1, 2 and 3 present the results of the treatments in the order of their effectiveness as indicated by the percentage of mites occurring on samples of 100 leaves taken 5 days after the sprays were applied. About 94 per cent of the mites were European red mites, the remaining individuals were mostly *Tetranychus schoenei* McG. Di(4-chlorophenoxy) methane ranked consistently among the most effective compounds or combinations listed in the three tables. Other promising materials used in all three sets of tests were dioctyl pthalate and parathion; but the latter compound in one of the four replicates included in the averages reported in table 2 gave practically no control. In general, tetraethyl pyrophosphate was more effective than hexaethyl tetraphosphate but both compounds were usually among the less effective treatments. On warm days the diluted hexaethyl tetraphosphate caused an irritation resembling hives on the face and arms of the spraymen including the writer. The erythema always continued for a couple of days and was alleviated by applying rubbing alcohol.

None of the materials or combinations caused injury on the fruit or foliage, but severe injury occurred in the form of black specks on the fruit when an application of hexaethyl tetraphosphate was made on trees which had been sprayed with bordeaux mixture about 10 days previously.

As used by orchardists during the past season, hexaethyl tetraphosphate was less effective than *DN-111*, and after a

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[1] *Dithane-14.*
[2] *Dn-111.*

Table 1.—Effect of adding a acaricide to orchard sprays containing 1.5 pounds of 50 per cent wettable DDT per 100 gallons of water; the acaricides being added in the third, fourth and fifth cover sprays ending June 10, 24, and July 23, 1947, respectively. Apple variety, Rome Beauty. Per cent of live mites as compared to 510 mites per 100 leaves from trees sprayed with DDT alone.

No.	Material and Quantity per 100 Gallons	On July 24	On July 28	Codling Moth Injuries[1]
1.	15% Parathion 1 lb.	6.8%	0.9%	1.4%
2.	Dioctyl pthalate 1 qt.[2]	1.9	2.9	6.7
3.	Hexaethyl tetraphosphate 1 pint	7.8	3.9	3.1
4.	40% di(4-chlorophenoxy) methane 1.25 lbs.	10.7	3.9	5.8
5.	Tetraethyl pyrophosphate 1 pint	2.9	16.6	6.3
6.	50% hexaethyl tetraphosphate 1 pint	37.2	23.5	9.9
7.	Hexaethyl tetraphosphate 1 pint	12.7	33.3	12.7
8.	80% 1,1-bis (chlorophenyl) ethane 1 pint	100.0	99.0	10.7
9.	Trees sprayed with 1.25 lbs. of 50% DDT, 2nd, 3rd, 4th and 5th covers			13.7
	Number of mites on 100 leaves on July 24	510		
	Number of mites on 100 leaves on July 28	3900		
10.	Check trees, not sprayed after the 1st cover spray			93.7
	Number of mites on 100 leaves on July 24	395		
	Number of mites on 100 leaves on July 28	2582		

[1] Includes data on fruit harvested in September and all drops from early July to harvest.
[2] *Grasselli Spreader*, 1 oz. added.

maximum of four applications, its use was discontinued in favor of the latter compound. The chief cause of the failure of hexaethyl tetraphosphate in commercial operations appeared to be due to the absence of any residual value against mites.

EFFECT OF CODLING MOTH.—For reasons of economy a desirable acaracide must be compatible with the ingredients used to control the codling moth. Therefore, most of the compounds included in this report were used in laboratory tests combined with 50 per cent wettable DDT to examine their biological compatibility. Some of the compounds reduced slightly the effectiveness of DDT, possibly on account of the wetting agent present. Others improved effectiveness slightly. The compound that increased effectiveness most in the laboratory and in the orchard (Table 1) was parathion.

Fruit picked from Stayman-Winesap trees sprayed with 15 per cent parathion, 3 pounds per 100 gallons of water, 7 and 8 days previously and subjected to attack of the codling moth larvae in the insectary showed 1.3 per cent live entries and 13.5 per cent total injuries as compared to 19.5 per cent live entries and 31.3 per cent total injuries on fruit from trees of the same variety and sprayed at

Table 2.—Results of tests to control mites on single trees of the Rome variety; series of July 12 and 24, 1947 at Winchester, Va. Average per cent of live mites as compared to the population per 100 leaves on check trees as indicated.

No.	Material and Quantity per 100 Gallons	1 Day After Spraying	5 Days After Spraying
1.	40% di(4-chlorophenoxy) methane 2.5 lbs.	18.3%	4.7%
2.	15% Parathion 1 lb.	15.8	5.7
3.	80% 1,1-bis (chlorophenyl) ethane 1 qt.	13.2	5.8
4.	Tetraethyl pyrophosphate 1 pint[1]	9.4	12.3
5.	Dioctyl pthalate 1 qt.[1]	17.1	16.2
6.	Dinitro compound[2] 1.25 lbs.	10.8	21.5
7.	Hexaethyl tetraphosphate 1 pint[3]	6.5	31.9
	Check trees, number of mites per 100 leaves		
	On July 11, 860		
	On July 25, 1635		

[1] *Grasselli Spreader*, 2 oz. added.
[2] *DN-111*. Contains 20% amine salt of dinitro-o-cyclohexylphenol.
[3] *Grasselli Spreader*, 2 oz. added in test of July 24.

the same time with 10.8 ounces of DDT (1 quart of 30 per cent DDT solution) in 100 gallons of water.

Further laboratory tests in which 15 per cent parathion was sprayed on apples at the rate of 1 and 3 pounds per 100 gallons of water indicated complete control on fruit suspended outdoors for 5 days before being subjected to attack of the codling moth larvae. Observations in the Stayman-Winesap orchard, however, indicated that the residue loses much of its effectiveness against the codling moth when the interval between sprays is extended to 14 days.

Table 3.—Results of tests to control mites on single trees of the Rome variety; series of August 12 to 15, 1947, showing average results of four replicates on successive days, excepting treatments No. 4, 5, 7 and 16 which represent only two replicates each. Average per cent of live mites as compared to the population found on the foliage of each tree just before spraying.

No.	Materials and Quantity per 100 Gallons	1 Day After Spraying	5 Days After Spraying
1.	40% di(4-chlorophenoxy) methane 1.25 lbs. *DN Dry Mix No. 1*[1] 3 oz.	17.7	2.8
2.	40% di(4-chlorophenoxy) methane 2.5 lbs.	8.8	3.4
3.	40% di(4-chlorophenoxy) methane 1.25 lbs. Dinitro compound[2] 10 oz.	11.7	4.9
4.	Dioctyl pthalate 1 qt.[3]	9.3	9.2
5.	50% flavan-oil composition 1 qt.[4]	34.2	15.6
6.	40% di(4-chlorophenoxy) methane 2.5 lbs. Bordeaux mixture 2-4-100 formula	29.9	15.7
7.	50% flavan-oil composition 1 qt. Bordeaux mixture 2-4-100 formula	40.5	15.7
8.	95% N-dodecyl-2-thiazolinyl sulphide 1 pint	21.6	18.2
9.	17.5% di(p-chlorophenyl) methyl carbonal 1 pint	45.9	22.5
10.	80% xanthone 1.25 lbs. Bordeaux mixture 2-4-100 formula	50.9	25.0
11.	80% xanthone 1.25 lbs.	34.6	31.5
12.	15% parathion 1 lb.	23.7	32.1
13.	50% tetraethyl pyrophosphate 1 pint	22.8	35.7
14.	15% parathion 1 lb. Bordeaux mixture 2-4-100 formula	39.4	46.5
15.	*DN-111*[2] 1.25 lbs.	47.2	50.7
16.	Dioctyl pthalate 1 qt.[3] Bordeaux mixture 2-4-100 formula	34.4	58.4
17.	50% hexaethyl tetraphosphate 1 qt.	45.8	62.3
18.	Hexaethyl tetraphosphate 1 pt.	41.0	78.0
Check, average number of mites per 100 leaves just before spraying, 1024			

[1] 40% dinitro-o-cyclohexylphenol.
[2] 20% amine salt of dinitro-o-cyclohexylphenol.
[3] 2 oz. *Grasselli Spreader* added.
[4] 50% hydroxypentamethyl flavan in oil.

Summary.—Of the new compounds used in all three series of tests to control European red mites, the following ranked among the more effective compounds: di(4-chlorophenoxy) methane, dioctyl pthalate and parathion. The latter compound was effective in controlling codling moth larvae for several days following an application and in combination with DDT formed the most effective treatment used to control the codling moth and mites. Limited tests with N-dodecyl-2-thiazolinyl sulphide showed sufficient promise to warrant more extensive tests. Hexaethyl tetraphosphate and tetraethyl pyrophosphate were erratic in effectiveness.

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Red-Banded Leaf Roller Control in Western New York in 1947[1]

S. W. Harman,[2] *New York State Agricultural Experiment Station, Geneva*

As in many other apple growing areas, the western New York fruit belt is experiencing a serious outbreak of the red-banded leaf roller *Argyrotaenia velutinana* Wlkr. It was a year ago, the fall of 1946, that our fruit growers first became concerned over the increasing amount of damage on apples. The outbreak was general and the injury varied from unimportant to 20 per cent of the crop in a few instances.

This past season (1947) the damage increased to three and four times that of a year ago. In a number of orchards there was practically a total loss of the crop. In such cases over 90 per cent of the fruit was injured and feeding areas showed on almost every leaf. The trees dropped three quarters of their fruit before picking time, and the injured fruit withered from loss of water and was subject to early decay.

Efforts to dispose of the damaged fruit were most discouraging. The presence of the caterpillars, webs and excrement on the apples was cause for rejection by federal inspectors as unfit for human consumption. Processors were not interested as the damaged fruit did not peel satisfactorily. Severely damaged crops had to be cleaned by either brushing or washing or both before they could be sold.

Prior to the present outbreak, injury to apple crops in western New York has usually been negligible in amount except for an occasional orchard. In such cases the damage rarely exceeded 10 per cent of the crop. These sporadic outbreaks were checked by the early summer sprays (petal fall and first cover) of lead arsenate as used in the spray program recommended for the codling moth. The important consideration was to coat the lower leaf surfaces where the young caterpillars fed.

The present unusual outbreak offered an opportunity to secure new information on control and the purpose of this paper is to present data gathered during the past season.

There are normally two full broods of the insect in western New York and during favorable seasons a trace of a third brood. The egg hatching period commences several days ahead of that of the codling moth and lasts for about 2 weeks. For this reason the sprays applied to control codling moth are also effective against the leaf roller.

Data from two heavily infested orchards representative of the results of several efforts at control carried on this past season are considered in detail.

Experiment 1.—This work was conducted in the John Goodrich orchard at Burt, New York in Niagara County for the purpose of determining the relative values of lead arsenate and DDT as controls for the red-banded leaf roller. The planting was one in which the insect had caused considerable damage in 1946. Twenty per cent of the crop of the variety Cortland was discarded as culls due to leaf roller injury. It is well known that fruit that sets thickly on the branches or grows in clusters is more subject to damage by this insect. Cortland is one of these sorts and for that reason was selected for the control studies. The orchard was set to Cortland, McIntosh and Delicious, but only the former variety was considered in the tests. McIntosh and Delicious fruits are usually well spaced on the branches and hang more as individual apples. For this reason they may be more effectively protected against leaf roller attack.

Four rows of trees in a section of the orchard adjoining a wood lot (which appeared to make for more favorable conditions for leaf roller infestation) were selected for the tests. Each row contained 10 mature bearing trees and was divided into two plots of five trees each. This provided eight plots in addition to the check trees which were not sprayed after the bloom period. The remainder of the orchard received DDT in the cover sprays and appears in table 1 as plot 9.

Sprays were applied with a modern

Eastern Branch Program.

[1] Journal Paper No. 740, New York State Agricultural Experiment Station, Geneva, New York, November 21, 1947.

[2] Died March 17, 1948.

high pressure orchard sprayer, the applications being made by the owner according to the plan of the experiment. Two leads were used, one from the top of the tank and another on a low rear platform where the liquid was directed upward to cover the under surface of the foliage as much as possible.

No appreciable injury was noticed until about the first of August when the second brood caterpillars appeared. By the middle of that month the worms were moving onto the fruit and observation of unsprayed trees indicated the presence of a large population. The crop was picked on the 8th of October at which time many worms were feeding on the fruit.

The data from the control tests are given in table 1. The percentages are the results of counting the total crop including dropped fruit from two Cortland trees in each plot.

A comparison of the data given in table 1 show that sprays of lead arsenate were outstandingly more effective in preventing red-banded leaf roller injury to apples than were sprays of DDT.

The data also imply that sprays applied early in the program, i.e., during June and July, were those most valuable in reducing the amount of injury.

EXPERIMENT 2.—Spray applications to combat the second brood of caterpillars during the month of August were made in a heavily infested 50 year old Baldwin orchard in which no lead arsenate had been used. The owner had applied DDT in the petal fall and first three cover sprays for codling moth. There were no further treatments in this orchard aside from the tests outlined in table 2.

Notwithstanding the summer treatment with DDT, the apple crop in this planting was, practically speaking, a total loss from the work of the red-banded leaf roller. Three quarters of the fruit dropped prior to harvest as a result of leaf roller injury.

The trees were large and umbrella shaped, allowing the spray to be thoroughly applied from underneath as well as from the outside. Experimental treatments were made with a modern high pressure orchard sprayer using 450 pounds pressure and applying ample liquid to wet thoroughly the trees from

Table 1.—Red-banded leaf roller control, 1947.[1]

Plot	Treatment (Amount in 100 Gallons)	6/3 Calyx Spray	6/12 10-Day Spray	Cover Sprays 6/26 1	7/9 2	7/24 3	8/7 4	8/18 5	9/2 6	Per Cent Damaged Apples
1	Lead arsenate 3 lbs.	+		+	+	+				19.2
2	Lead arsenate 3 lbs.	+	+	+	+	+				5.8
3	Lead arsenate 3 lbs.	+	+	+	+	+	+			2.0
4	Lead arsenate 3 lbs.	+	+	+	+	+	+	+		0.9
5	DDT, 2 lbs. 50-W[3]	LA[2]		+	+	+				48.7
6	DDT, 2 lbs. 50-W	LA	LA	+	+	+				21.5
7	DDT, 2 lbs. 50-W	LA	LA	+	+	+	+			19.9
8	DDT, 2 lbs. 50-W	LA	LA	+	+	+	+	+		14.7
9	DDT, 2 lbs. 50-W	LA	LA	+	+	+	+	+	+	12.3
10	Check, no sprays after bloom									71.8

[1] Tests were made in the John Goodrich orchard at Burt, N. Y.
[2] LA=lead arsenate 3 lbs. used in the calyx and 10-day sprays prior to the DDT program.
[3] 50 per cent wettable powder.

Table 2.—Red-banded leaf roller, second brood control, 1947.[1]

Plot	Treatment (Amount in 100 Gallons)	Applications Aug. 7	Aug. 20	Per Cent Damaged Apples
1	DDT, 1 lb.[2]	+		64.3
2	DDT, 1 lb.[2]	+	+	65.6
3	DDT, 1 lb. in benzene[3]	+	+	66.9
4	DDT, 2 lbs. in benzene	+	+	24.5
5	Lead arsenate, 3 lbs.	+		42.3
6	Lead arsenate, 3 lbs.	+	+	24.5
7	DDT, 1 lb.+lead arsenate, 3 lbs.	+		49.1
8	DDT, 1 lb.+lead arsenate, 3 lbs.	+	+	16.0
9	Parathion, 3 lbs., 15% wettable powder[4]	+	+	4.5
10	Check, no August sprays			84.4
11	Check, no August sprays			91.5

[1] This work was done in the Harry Brown orchard at Waterport, N. Y.
[2] Applied as "Deenate" using 2 pounds of 50% wettable powder in 100 gallons.
[3] Prepared by dissolving 1 pound technical DDT in 1 quart benzene and using as an emulsion in 100 gallons of water.
[4] Product of American Cyanamid Company.

both beneath and outside. The treatments and results expressed as percentage damaged fruit are given in table 2.

Judging from the amount of injury that developed throughout the orchard as a whole as well as on the check trees, the early season sprays with DDT applied by the owner were of little value as a control for the leaf roller. These trees received a petal fall and three cover sprays of one pound of DDT in 100 gallons for the codling moth prior to the experimental tests made against the second brood of leaf roller caterpillars in August.

A study of table 2 indicates that the control resulting from the use of either lead arsenate or DDT in August as applied in this orchard was not satisfactory. Lead arsenate at 3 pounds, Fig. 2, in 100 gallons as compared with DDT, at 1 pound was unquestionably the more effective of the two. By doubling the concentration of DDT to 2 pounds in 100 gallons, the control was similar to that with lead arsenate.

A new insecticide, parathion was by far the most efficient material used against the red-banded leaf roller. This new insecticide, was first produced by German workers. It is an esther of thiophosphoric acid and was produced and made available during the past year for experimental purposes by the American Cyanamid Company.

The experience of many fruit growers and also other experimental evidence confirmed the results of the tests reported above. By the end of the season there was little doubt that DDT was not the answer to the problem. The use of as few as one or two lead arsenate applications in June saved many apple crops from serious damage. There were a number of instances in which growers using lead arsenate produced good crops of fruit while neighbors on all sides who relied on a straight DDT program experienced serious losses. There were also a number of the better growers who used lead arsenate in the petal fall spray and again 10 days later, and then by careful inside and outside spraying with six or more cover sprays of DDT were able to hold the injury to a low figure. This program, however, was considered too strenuous and expensive to be practicable. In other words, it was a losing battle to try to fight the red-banded leaf roller with DDT in a problem orchard.

SUMMARY.—Prior to the introduction of DDT in our apple spray program, lead arsenate provided adequate control of the red-banded leaf roller when properly applied. Occasional outbreaks in individual orchards were combated with arsenical sprays directed to protect the lower leaf surface where the newly hatched caterpillars are found.

The results of all attempts at control during 1947 showed outstanding superiority of 3 pounds of lead arsenate over DDT used at the 1 pound in 100 gallons. This would indicate that the substitution of DDT for lead arsenate in the apple spray program may have been an important factor in bringing about our present problem with the red-banded leaf roller.

Sprays applied during June, directed against the first brood caterpillars, were much more successful in preventing injury to the fruit than August applications made at the time the second brood larvae were active.

The most outstanding insecticide used in the control tests was the new material parathion.

The method of application, whatever the material used, was very important. To be effective, sprays had to be directed to cover the lower leaf surface where the young caterpillars were feeding.

HUGH GLASGOW SERIOUSLY ILL

Dr. Hugh Glasgow, Head of the Division of Entomology of the New York Agricultural Experiment Station at Geneva has been seriously ill for the past two months. At present reports it cannot be less than a month before he is able to return to his duties. Dr. Glasgow's many friends will wish to extend their sympathy and best wishes.

Two Years of Experience with Mist Blowers for Control of Apple Pests

PHILIP GARMAN, *Connecticut Agricultural Experiment Station, New Haven*

After two years work with the mist blower method for control of apple pests it seems advisable to present some of our conclusions regarding its general usefulness. Apparent advantages lie in:

(1) Ease of operation compared with standard outfits.
(2) The small amounts of water or solution carried and the large number of trees sprayed with one filling.
(3) Lack of removal of previous sprays.
(4) Feasibility of spray and dust applications with one machine.
(5) Speed of operation. (To date we have been able to cover about two acres per hour, but we believe this rate can be increased.)

Disadvantages are:

(1) Difficulty of operating in moderate winds. (Mist does not settle on the foliage well in windy periods.)
(2) Concentrates are not agitated sufficiently in the outfits used so far. Different agitation may be necessary for concentrates as compared with the usual dilutions.
(3) Complete cover of all parts of the tree is sometimes difficult to obtain even in quiet periods due to lack of flexibility in the machines themselves.
(4) Some of the nozzles used are definitely unsuited to the application of concentrates; all could be improved.

GENERAL CONCLUSIONS.—(1) Suitable pest control *can* be obtained with mist blowers. (2) The main problems are mechanical and more study from an engineering standpoint is highly desirable. (3) We are not yet ready to recommend the mist blower as a replacement for older conventional sprayers. (4) We must continue to work with the method which appears sound in theory and will, we feel certain, eventually increase the speed and ease of apple pest control. Being an entirely new tool, we must learn how to use it.

DISCUSSION.—The figures in the tables represent data obtained in four different orchards in 1947. While not indicated in the programs given with the tables, we also applied dormant oils and DN sprays with the apparatus described. For dormant sprays, oil at 25 per cent and DN, 16 quarts to 100 gallons were used.

Our 1946 tests consisted of randomized plots at Mount Carmel. Here the fruit was examined by sampling both picked and drops and inspecting each apple of the sample individually. The 1947 tests were much larger and consisted of approximately two acres divided into two plots, in three different orchards—all within a radius of 15 miles of New Haven. This year examination of four of the plots was done shortly before harvest while the apples were still on the trees. Two of the plots, both in the Plumb Orchard, were sampled as in 1946, and the apples of the sample examined individually.

From the tables it is apparent that the most serious problem during 1946 was scab control yet, in spite of the seriousness of the situation it was possible to obtain reasonably clean fruit with a minimum number of sprays. During both years insects have been handled well, though, had codling moth been more severe, we might have had more serious trouble because of the thin deposits in the top centers of the trees. Maggot control is not shown in the table, but paralleled that of other pests. In only one case did the control appear to be poor, that of the sulfur plot in the Plumb Orchard for 1947. As may be deduced from table 1, russetting is not seriously increased even on tender varieties such as Baldwin. Lack of color was apparent in some of the blocks treated with *Fermate*, but this was no different from others treated with the same material in the usual manner. Only one of our plots became infested with European red mites—again the sulfur plot in the Plumb Orchard.

Most of our work has been done (except for the dormant sprays) with mixtures carrying approximately two pounds of solids per gallon, but reduced in late season to avoid heavy residues. With this concentration and the whirl jet nozzle,[1] we had much less clogging than in 1946. The rate of application for medium and large trees commercially pruned, was 3 to 5 quarts per tree in 1947 and 2 quarts in 1946.

It has been argued that the type of

Eastern Branch Program.

[1] Spraying Systems Co., 4021 Lake St., Chicago, Illinois.

cover being discontinuous, control of diseases and insects cannot be secured. Figure 1 gives an idea of what frequently happens when the mist sprayed deposit is subjected to weathering for a few days. Similarly, after several successive applications, the foliage becomes more and more completely covered and doubtless accounts for some of the favorable results that have been obtained. There is, of course, no removal of previous deposits by succeeding applications.

1946. From table 1 it is evident that general insect and disease control was nearly or quite as good with five mist sprays as was obtained with 11 or 12 with conventional apparatus. In the case of the *Fermate* treatment, scab was held to a lower figure than any other method or formulation. For the Baldwins, there is no significant difference either in russet or amount of clean fruit between the mist blower plots and those sprayed with conventional rig. Maggot control not

Table 1.—Pest control 1946. Niagara mist blower vs. standard equipment.

Treatment	Good Minus Russeted Fruit	Good Including Russet	Scab	Russet
	(Per Cent)			
McIntosh				
1. Sulfur-lead arsenate 11 sprays—*hydraulic rig*	93.22	96.64	1.64	3.42
2. Sulfur-lead arsenate 12 sprays—*hydraulic rig*	88.61	93.14	4.38	4.53
3. Sulfur-lead arsenate concentrates 5 sprays—*mist blower*	77.21	84.03	13.37	6.82
4. Fermate-lead arsenate concentrates 5 sprays—1 dust. *mist blower*	82.92	97.22	1.16	14.30
Baldwin				
1. Sulfur-lead arsenate 11 sprays—*hydraulic rig*	77.64	96.90	—	19.26
2. Sulfur-lead arsenate 12 sprays—*hydraulic rig*	76.63	97.81	—	21.18
3. Sulfur-lead arsenate concentrates 5 sprays—*mist blower*	71.78	96.47	—	24.69
4. Fermate-lead arsenate concentrates 5 sprays—1 dust. *mist blower*	74.48	94.78	—	20.30

Spray Dates and Formulae

1946

Treatment 1. April 17, 24, May 10, 17, 23, 29–31, June 7, 17, 25, July 5, 25
2. Same as 1 with one extra spray April 23
3. April 29, May 14, 30–31, June 15, July 15
4. April 23, 29, May 14, 30–31, June 15, July 15

Hydraulic spray formula

1 and 2. Lead arsenate 3 lbs., early, 2 lbs. in late season
Wettable sulfur[1] 4 lbs. early, 3 in late season
Lime 3 lbs. early, 2 in late season

Mist blower formula

3. Dry wettable sulfur[1]	5 lbs.
Lead arsenate	3 lbs.
White mineral oil	1 pint (omitted in last spray)
Water to 4 gallons	
Total solids per gallon	*2 lbs.*

Mist blower formula

4. *Fermate* (75% active)	1.5 lbs.
Lead arsenate	6.0 lbs.
Daxad dispensing agent	1 oz.
Skim milk powder	6 oz.
White mineral oil	3 pints (omitted in last spray)
Water to 4 gallons	
Total solids per gallon	1 lb. 15 oz.

[1] Dow Chemical Co. *Mike.*

Table 2.—Control of orchard pests with bean mist blower—1947.

ORCHARD	VARIETY	FORMULA	GOOD	CURCULIO	SCAB	OWNER SPRAYED
			Per Cent			
Plumb	Rome	Sulfur	73.51	2.27	20.68	—
Plumb	Rome	*Fermate*	93.38	1.20	3.85	—
Plumb	McIntosh	Sulfur	41.16	4.00	55.05	—
Plumb	McIntosh	*Fermate*	77.72	1.87	20.18	—
Bishop	McIntosh	Sulfur	56.04	1.18	42.86	worse
Bishop	McIntosh	*Fermate*	85.32	1.93	12.06	worse
Bishop	Delicious	Sulfur	42.60	1.18	8.28	worse
Bishop	Delicious	*Fermate*	78.13	3.13	14.84	worse
Barnes	McIntosh	Sulfur	93.80	.77	4.65	better
Barnes	McIntosh	*Fermate*	90.88	2.79	5.00	better

Number of sprays:
Plumb orchard— 9—(1 dormant oil, 1 D).
Bishop orchard—10—(1 dormant oil)
Barnes orchard—10—(2 dormant by owner).

SPRAY DATES AND FORMULAE

1947

Plumb Orchard. April 28, May 15, 28, June 9, 20–23, July 7, 28
Bishop Orchard. April 26, May 7, 15, 27, June 10, 20–23, July 3, 8, 29
Barnes Orchard. May 7, 24, 28, June 10, 30, July 5, 7, 29

Mist blower formulae

Fermate	.42 lb. per gallon (early)
Sulfur	1.2 lbs. per gallon (early)
Fermate-lead arsenate	2.0 lbs. per gallon, early.
	1.2 lbs. per gallon, mid-season
	.8 lb. per gallon, late
Sulfur-lead arsenate	2.0 lbs. per gallon, early
	1.0 lb. per gallon, mid-season
	.5 lb. per gallon, late

Small amounts of mineral or vegetable oil stickers were used early in the season together with emulsifying agents, but were omitted after June 15

shown in the tables) was satisfactory in all plots.

1947. The data obtained in 1947 is set forth in tables 2 and 3. Curculio control was good to excellent, but the sulfur mist blower job was considered a failure in scab control. In three of the five comparisons of the sulfur and *Fermate* the latter was better for scab (Table 2), while in the fourth, it was almost equal. Compared with owner-sprayed areas, the plots in one orchard were better, but worse in another. In both of these orchards the scab situation became so bad that it was necessary to apply one Puratized spray with high pressure outfits. However, check trees

Table 3.—Comparison of mist blower and hydraulic rig. Plumb orchard—1947.

MATERIALS	NO. SUMMER SPRAYS	VARIETY	PERCENTAGE	
			Good	Scab
Fermate-Lead Arsenate puratized—*hydraulic rig*	7	McIntosh	82.97	13.32
Fermate-Lead Arsenate—*mist blower*	7	McIntosh	77.72	20.18
Sulfur-Lead Arsenate—*mist blower*	7	McIntosh	41.16	55.05
Fermate-Lead Arsenate puratized—*hydraulic rig*	7	Rome	93.57	4.93
Fermate-Lead Arsenate—*mist blower*	7	Rome	93.38	3.85

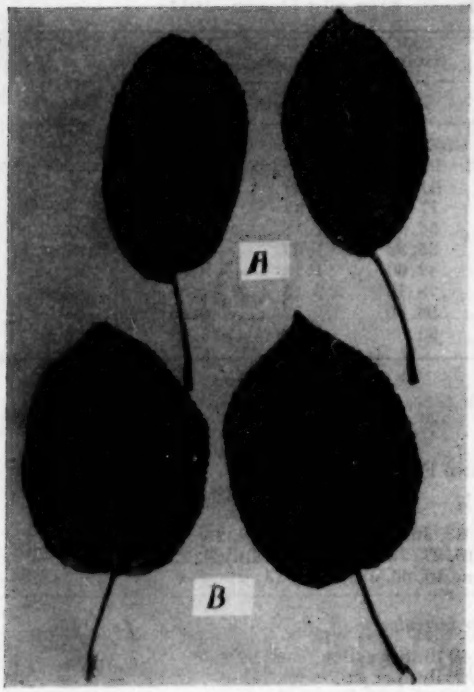

FIG. 1.—Type of deposit obtained from mist blower application of wettable sulfur-lead arsenate concentrate. A. Shortly after spray. B. Leaves from same tree after two or three days of damp weather. Note uniform distribution of deposit.

left at the time of this spray indicated that the treatment had litle over-all effect on the scab. In the Plumb Orchard, table 3 comparisons of *Fermate*, mist blower work and high pressure spray plots show the same degree of control for Romes, but much inferior for McIntosh. This is due to the fact that the McIntosh trees are much larger than the Romes and the problem, therefore, becomes one of coverage as well as actual pest control. Maggot control was satisfactory in the Plumb Orchard *Fermate* plot, but unsatisfactory in the sulfur plot. The other two orchards were not examined for maggot, but appeared from casual external examination to be free of the pest.

All the plots treated in 1947 contained very large trees and at least two of them were in locations subject to scab. The Plumb Orchard is particularly subject, being as bad as any in the state. Curculio and maggot infestations are also severe in the Plumb Orchard.

EQUIPMENT.—Our 1946 experiments were made with a converted Niagara duster provided with a 30-gallon water tank and a two-cylinder pump driven with a belt connected with the power shaft. The nozzle arrangement consisted of a single oil burner type nozzle inverted in the end of the air discharge tube. Endless trouble developed from clogging so that the nozzle was discarded at the end of 1946.[1]

In 1947 a large duster-sprayer[2] with two-cylinder pump and a special nozzle manifold for spreading the air and giving more even cover was made available. The triple broom-like manifold was first operated in a vertical position but later was changed to horizontal because of improved deposits when operated in that position. Whirl-jet nozzles, a single one inverted in each of the three outlets gave little trouble from clogging. The size of the nozzle orifice is 0.06 inch and estimated delivery (3 nozzles) at 75 pounds pressure is 3 quarts per minute. Actually the delivery was nearer a gallon per minute in our tests.[4]

[1] Changes in the duster to adapt it to mist spraying was done by R. A. Spencer of the Connecticut Agricultural Experiment Station.

[2] Bean Mfg. Co.

[3] All the above-mentioned work has been in cooperation with S. F. Potts of the U. S. Department of Agriculture, who has been instrumental in developing the machines for mist applications. For further details refer to Potts & Friend, 45th Report of the Connecticut State Entomologist, Bul. 501, pp. 47–60, 1946.

[4] The special manifold was constructed by John Fraser of Amden, Connecticut.

Control of Peach Insects with New and Old Insecticides

CASTILLO GRAHAM, *University of Maryland*

In 1946, experiments were conducted to test the comparative efficiency of benzene hexachloride, benzene hexachloride plus DDT, DDT plus acid lead arsenate, acid lead arsenate and basic lead arsenate, in the control of the plum curculio and insects that cause cat-facing of peaches. Records were taken on the injury to foliage and twigs resulting from these treatments. The sprays were applied by the grower under the direction of the writer and each plot received two applications of the insecticides, one in the petal fall and the other in the shuck slip stage.

Curculio data was obtained by examining the drop peaches from 30 trees in each plot. Cat-facing data was obtained by examining the peaches from 3 trees in each plot. The data on foliage injury was obtained by counting the number of leaves on the ground from 5 trees in each plot on June 10 and 27, and the data on twig injury by examining the base of the current season's growth on 50 twigs in each plot (Tables 1 and 2).

The results obtained in 1946 with benzene hexachloride were favorable enough to make it desirable to continue the work in 1947. That year a block of 4 year old trees surrounded on three sides by woods and on the other side by an old peach orchard was selected for these tests. Cur-

Table 2.—Leaf and Twig Injury, 1946 Experiments.

Plot No.	Average Number Leaves on Ground per Tree		Number Twigs Examined	Number Twigs Injured
	June 10	June 27		
1	649	192	50	47
2	597	173	50	50
3	697	362	50	50
4	499	225	50	50
5	31	86	50	0
6	22	139	50	2

Table 1.—Experiments of 1946.

Plot No.	Spray Materials per 100 Gallons	Peaches Examined	Number Injured	Per Cent Injured
1	Petal fall & shuck sprays 4 lbs. basic lead arsenate 4 lbs. lime	For curculio 1117	55	4.92
		For cat-facing 1639	84	5.18
2	Petal fall & shuck sprays 4 lbs. basic lead arsenate 4 ozs. DDT 4 lbs. lime	For curculio 1020	42	4.11
		For cat-facing No record		
3	Petal fall & shuck sprays 2 lbs. acid lead arsenate 3 lbs. zinc sulfate 2 lbs. lime	For curculio 1225	21	1.71
		For cat-facing 785	33	4.2
4	Petal fall & shuck sprays 2 lbs. acid lead arsenate 3 lbs. zinc sulfate 4 ozs. DDT	For curculio 1338	28	2.09
		For cat-facing 1045	5	.45
5	Petal fall & shuck sprays 3 lbs. benzene hexachloride	For curculio 2000	49	2.45
		For cat-facing 1159	46	3.96
6	Petal fall & shuck sprays 3 lbs. benzene hexachloride 6 ozs. DDT	For curculio 1800	58	3.22
		For cat-facing 1277	30	2.35

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culio and cat-facing had been a serious problem in the old orchard for several years.

In the spring, the orchard was seeded to rye and vetch and heavily fertilized resulting in a heavy growth. The trees received three applications of nitrate and were extremely vigorous throughout the growing season.

Forty-five rows having from 4 to 6 trees per row were selected for the test. Fifteen formulations of sprays, each replicated three times were used in the experiments. Some plots received 5 spray applications starting in the pre-blossom and others 4 applications starting in the petal fall stage. The intervals between the last 4 sprays were approximately 8 days.

Records were made on each peach in the entire block. Drop peaches were picked up on three different occasions and each peach examined for cat-facing, then cut and examined for curculio. At harvest time, each peach was examined for cat-facing, curculio scars, visible and invisible injury of oriental fruit moth. A high percentage of the peaches at harvest had injuries that could not be attributed to any particular insect. The injured spots were covered with gum, or had small tentacles of gum protruding from the scar. These scars had previously been attributed to oriental fruit moth by the writer, but upon closer examination with a microscope, appeared to be caused by one of the stink bugs. This type of injury is designated as stings. On June 19 records were made on the number of leaves on the ground from each tree in each plot (Tables 3 and 4).

Table 3.—Experiments of 1947.

Plots	Material Used	Cat-facing	Stings	Oriental Moth	Curculio Worms	Curculio Scars	Clean Fruit
		Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
1	1 lb. benzene hexachloride plus ½ lb. DDT in petal fall, shuck, 1st & 2nd cover sprays	13.4	13.43	64.13	5.49	4.34	0
2	1 lb. DDT in pre-blossom, 2 lbs. benzene hexachloride in petal fall, shuck, 1st & 2nd cover sprays	21.4	20.41	56.14	2.65	8.95	0
3	2 lbs. benzene hexachloride plus 1 lb. sticker[1] in petal fall, shuck, 1st & 2nd cover sprays	15.9	15.14	52.38	.98	5.80	9.8
4	2 lbs. benzene hexachloride in pre-blossom: 1 lb. benzene hexachloride plus ½ lb. DDT in petal fall, shuck, 1st & 2nd cover sprays	15.82	11.51	39.37	5.61	4.11	23.58
5	Acid lead arsenate	21.04	6.31	53.13	20.55	5.35	0
6	1 lb. DDT in pre-blossom, 1 lb. benzene hexachloride plus ½ lb. DDT in petal fall, shuck, 1st & 2nd cover sprays	17.10	17.75	38.58	4.72	4.0	17.85
7	2 lbs. benzene hexachloride plus 1[2] pt. 50% hexaethyl tetraphosphate in petal fall, shuck, 1st & 2nd cover sprays	20.12	19.09	67.57	1.83	6.22	0
8	Check—no treatment	13.27	14.01	61.30	18.06	6.83	0
9	2 lbs. benzene hexachloride in petal fall, shuck, 1st & 2nd cover sprays	15.68	14.98	69.16	.99	3.10	0
10	4 lbs. *Ryanex*[3] in pre-blossom, petal fall, shuck, 1st & 2nd cover sprays	15.33	17.76	64.25	15.72	11.33	0
11	2 lbs. benzene hexachloride in pre-blossom, petal fall, shuck, 1st & 2nd cover sprays	13.42	18.90	58.19	1.53	1.91	6.05
12	2 lbs. benzene hexachloride plus 1 pt., 50% hexaethyl tetraphosphate[2] in pre-blossom, petal fall, shuck, 1st & 2nd cover sprays	21.35	12.34	55.78	3.29	2.34	4.9
13	3 lbs. bis(methoxyphenyl)[4] trichloroethane in pre-blossom, petal fall, shuck, 1st & 2nd cover sprays	26.41	12.41	61.11	4.14	1.40	0
14	5%[5] bis(methoxyphenyl) trichloroethane aerosol in petal fall, shuck, 1st & 2nd cover sprays	11.10	8.69	77.55	4.91	1.13	0
15	2 lbs. benzene hexachloride plus 1 lb. Linck Wa in pre-blossom, petal fall, shuck, 1st & 2nd cover sprays	10.0	16.46	64.66	.84	4.0	4.04

[1] B. F. Goodrich Chemical Co.
[2] California Spray Chemical Co.
[3] Merck & Co., Inc.
[4] E. I. Du Pont De Nemours & Co., Inc.
[5] 5% bis(methoxyphenyl) trichloroethane, 10% *Velsicol AR-60*, 35% acetone, 40% methyl chloride, 10% carbon doxide. Victor Products Corp.

During July, an extremely heavy infestation of oriental fruit moth occurred both in the experimental plots and in the remainder of the orchard that was being sprayed by the owner. The vigorous growth of the young trees furnished ideal conditions for oriental fruit moth. Four plots, each consisting of 45 trees, were selected for control tests. Records were made by examining all the peaches from the plots for visible and invisible injury at harvest time. The materials used, dates of application, number of peaches examined, and per cent infested with oriental fruit moth, are shown in table 5.

DISCUSSION.—The infestation of curculio and the insects that cause cat-facing of peaches was so light in the orchard where the experiments were conducted in 1946 that the experiments indicated only the desirability of continuing the work.

Studies made on the phytotoxicity of the different materials to the foliage and twigs of the tree showed that acid lead arsenate was the most toxic with basic lead arsenate next and no injury either to the foliage on twigs resulted from the use of benzene hexachloride. The trees sprayed with benzene hexachloride had better color and made better growth than either of the other plots.

The date presented in table 3 shows that the insects that cause cat-facing of peaches were not controlled with any of the spray combinations. used. There was no noticeable difference in the control of these insects between the plots that received 5 applications of spray starting in the preblossom, and 4 applications starting in the petal fall. The percentage of stings, which was attributed to two species of stink bugs, *Euschistus servus* (Say) and

Table 4.—Leaf injury, 1947 experiments.

PLOT NO.	DATE RECORDS WERE TAKEN	AVERAGE NO. LEAVES PER TREE ON GROUND IN EACH PLOT
1	June 19	54
2	June 19	35
3	June 19	29
4	June 19	33
5	June 19	641
6	June 19	34
7	June 19	16
8	June 19	56
9	June 19	47
10	June 19	38
11	June 19	56
12	June 19	16
13	June 19	34
14	June 19	42
15	June 19	63

Acrosternum hilare (Say), was high on all plots, except plots 5 and 14. The comparatively small amount of stings on Plot 5, which was sprayed with acid lead arsenate, is attributed to the thin foliage, probably making it less desirable for these insects. It appears that the aerosol used on Plot 14 was somewhat more effective in controlling these pests than any of the other materials used.

The 3 plots that had DDT incorporated in the spray program had an average of about 10 per cent less oriental fruit moth than the average of all the other plots.

Good commercial control of the plum curculio was obtained with all spray combinations containing benzene hexachloride. The plots sprayed with lead arsenate and *Ryania* were no better than

Table 5.—Oriental fruit moth experiments, 1947.

MATERIALS USED	DATES APPLIED	NO. PEACHES EXAMINED	PER CENT ORIENTAL FRUIT MOTH
1 lb. DDT per 100 gals. of spray	July 22	3397	25.72
1 lb. DDT per 100 gals. of spray	July 22	4379	12.85
1 lb. DDT per 100 gals. of spray	Aug. 4	10083	18.68
Check		4272	53.95

the checks which received no treatment except sulfur sprays.

The data on the phytotoxicity of the insecticides to the foliage and twigs showed that of all of the combinations used lead arsenate was the only material that caused any injury.

The data on oriental fruit moth showed that one application on July 22 was less effective than one on August 4, and the two applications, one on July 22 and one on August 4 were most effective than either of the single applications. The variety of peaches on these and the other experimental plots was Shippers Late Red. The peaches on all plots were harvested on September 6.

CONCLUSION.—Benzene hexachloride gave better control of the curculio than the standard treatments and moreover produced less leaf and twig injury. It failed to control cat-facing. Oriental fruit moth was not satisfactorily controlled by the use of DDT in the early sprays; however, when applied in later sprays, it was much more effective.

Plum Curculio Control in North Carolina[1]

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Recommendations for plum curculio control in the past have usually included burning of debris around the edge of orchards and adjoining woods, spraying with lead arsenate, and picking up drops. This paper deals with (1) the place of hibernation of the curculio and the value of destroying these hibernating quarters by burning; and (2), the results of field tests with some of the newer insecticides, *i.e.* benzene hexachloride, hexaethyl tetraphosphate, and chlorinated camphene as compared with lead arsenate.

Plum curculio damage to peaches in North Carolina was especially severe in 1945 and 1946. Many orchards had over 50 per cent wormy fruit at harvest and consequently a large population of adults for hibernation during the fall of 1946. This provided a better than usual opportunity to check on the place of hibernation and the value of burning the debris around the edges of the orchards and woods as a control measure.

LOCATION OF CURCULIOS IN DEBRIS.—Before starting the experiment on burning it was deemed advisable to substantiate the findings of Quaintance & Jenne (1912) and Snapp (1930), that the majority of curculios hibernate in the debris or immediately above the soil surface. In order to check further on this, two 1-square yard samples were taken up in three separate horizontal layers. The first layer of the samples consisted of the current year's leaves which were very fluffy. The second layer was old leaves and other debris which was starting to decay. The third layer consisted of the first two inches of the soil. In both samples, all curculios were found in the old debris just above the soil. Snapp (1930) reported finding a few curculios in the soil, but most of them occurred in the older debris.

Samples were also taken 50 and 100 yards from the edge of the woods, but curculios were not found in either area. Neither was it possible to find any curculios in the debris from the areas where peach trees had died and the grass and leaves had been allowed to accumulate.

Considerable time was also spent looking for curculios under the bark of peach, pine, and oak trees, but none were found. However, they have been reported as occurring under bark as well as around buildings and under lumber (Quaintance and Jenne 1912; Snapp 1930).

BURNING AS A SUPPLEMENTARY CONTROL.—Burning the debris around the edges of peach orchards is a rather common practice and has been recommended as a supplementary control measure for the plum curculio. Leiby (1923) reports that burned areas near Aberdeen, North Carolina, showed a reduction of 62 per cent. Graham (1938) reported that burning decreased the populations by 50 per cent in Maryland. Many growers in North Carolina burned the debris in the woods and around the edges of their orchards during the winter of 1945–46. However, so many curculios entered their orchards in 1946 that they had to carry out as thorough a control program as the growers who did not burn the debris.

During the winter of 1946–47 an experiment was set up at Candor, North Carolina, to determine the effectiveness of burning. Two orchards which had over 50 per cent wormy fruit in 1946 were selected. The debris in the woods around the edge of the "test" orchard had not been burned for several years prior to the time it was burned January 28, 1947. The debris around the "check" orchard had been burned during the winter of 1945–46 but it was not burned during the winter of 1946–47. The results of burning the debris were determined (1) by checking on the number of curculios per square yard in the debris around the "test" orchard before and after burning; and (2) by checking on the relative number of curculios in each orchard in the fall and spring.

Table 1 shows that there was an average of three curculios per square yard before burning. After burning there was less than one curculio in four square yards. This indicates better than 90 per cent control of the curculios in the debris around the orchard and it would appear that burning might be an effective supple-

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[2] Research Entomologist.

mentary control measure for the plum curculio. However, judging from the relative numbers of curculios in the border rows of the orchards in the fall of 1946 and the spring of 1947 (Table 2), burning around the test orchard was of no value.

Table 1.—Effect of burning debris around orchard.

	Date Sampled	Number Samples	Total Curculios	Samples with Curculios	Average Curculios per Sq. Yd.
Before Burning	11/14/46	3	9	3	3
	1/28/47	4	12	2	3
After Burning	1/29/47	6	1	1	$\frac{1}{6}$
	2/ 6/47	4	1	1	$\frac{1}{4}$

The difference in the average number of curculios in the test orchard and the in check orchard may be explained by the fact that there were 75 acres in the test orchard and only 5 acres in the check orchard. Thus, it is reasonable to expect as greater number of curculios to go across the outside rows of the test orchard as is indicated in Table 2.

FIELD TESTS WITH INSECTICIDES.—For the major plum curculio field tests in 1947 five orchards were selected in the Sand Hills area of North Carolina (Table 3). Benzene hexachloride[1] and lead arsenate were used in four of these orchards.

Table 2.—Effect of burning debris around orchard on abundance of curculios in orchards.

	Average Number Curculios per Tree		
	April 11 1946	Sept. 19 1946	April 9 1947
Test Orchard Debris Burned 1/28/47	36	30	36
Check Orchard Debris not Burned	—	10	12

The fifth orchard, the check, was not sprayed.

Orchard 1 (Elberta) had a very heavy infestation of curculios in 1946—over 50 per cent of the fruit being wormy at harvest time. This orchard of approximately 75 acres was divided into 3 blocks of 25 acres each and sprayed with a stationary boom sprayer (Fig. 1).

Orchard 2 (Golden Jubilee) had a light infestation in 1946. The acre designated as the lead block was on a corner with woods on one side, an open field on one side, and orchard on the other two sides. The remainder of the orchard, about 70 acres, is designated as the benzene hexachloride block. However, records from the BHC block were taken from an area adjacent to the lead block. A stationary boom sprayer was used in this orchard.

Orchard 3 (Yo-Yo, a Hale type peach) had over 50 per cent wormy fruit in1946. It was an isolated orchard of six acres which was divided into two blocks of three acres each. The sprays were applied with two four-nozzle brooms.

Orchard 4 (Elberta) had a moderate infestation of curculios in 1946. The sprays were applied with a *Speed Sprayer*.

Orchard 5 (Elberta) had over 50 per cent wormy fruit in 1946 and 60 per cent in 1947. This is an isolated orchard of approximately 5 acres which was not sprayed during 1946 or 1947.

Peach drops were picked up regularly in Orchards 1, 2, and 4, but they were not picked up in Orchards 3 and 5.

FIG. 1.—Stationary boom sprayer.

[1] All of the benzene hexachloride was labeled as containing 6 per cent gamma.

Table 3.—Sprays used in test orchards 1947.

Orchard	Block and Size	Materials per 100 Gal.	Dates Applied	Area Sprayed
1	Lead—25 acres	Cryolite—4 lbs.	4/12; 4/16	Outside rows
		Acid lead arsenate—2 lbs.; Sulfur; safeners[1]	4/21; 4/29; 6/20	Entire block
1	Benzene hexachloride —25 acres	Cryolite—4 lbs.	4/12; 4/15	Outside rows
		Benzene hexachloride—4 lbs.; Sulfur—6 lbs.	4/21; 4/28	Outside rows
		Benzene hexachloride—4 lbs.; Sulfur—6 lbs.	4/17; 4/25; 5/1	Entire block
		Acid lead arsenate—2 lbs.; Sulfur; safeners[1]	6/20	Entire block
1	Benzene hexachloride —25 acres (1st Brood only)	Cryolite—4 .lbs	4/12; 4/15	Outside rows
		Benzene hexachloride—4 lbs.; Sulfur—6 lbs.	4/21; 4/28	Outside rows
		Benzene hexachloride—4 lbs.; Sulfur—6 lbs.	4/17; 4/25; 5/1	Entire block
2	Lead—1 acre	Cryolite—4 lbs.	4/10	Outside rows
		Basic lead arsenate—4 lbs.; Sulfur; safeners[2]	4/12; 4/22; 4/30; 6/10	Entire block
2	Benzene hexachloride —70 acres	Cryolite—4 lbs.	4/10	Outside rows
		Benzene hexachloride—4 lbs.; Sulfur—6 lbs.	4/15	Outside rows
			4/16; 4/22; 4/30; 6/10	Entire orchard
3	Lead—3 acres	Cryolite—4 lbs.	4/5	Entire block
		Acid lead arsenate—2 lbs.; Sulfur—6 lbs.; hydrated lime —6 lbs.	4/12; 4/19; 4/26; 6/24	Entire block
3	Benzene hexachloride —3 acres	Cryolite—4 lbs.	4/5	Entire block
		Benzene hexachloride—4 lbs.; Sulfur—6 lbs.	4/12; 4/19; 4/26; 5/3; 6/24	Entire block
4	Lead—1 acre	Benzene hexachloride—3 lbs.	4/16	Entire block
		Acid lead arsenate—2 lbs.; Sulfur—6 lbs.; hydrated lime —10 lbs.; zinc sulfate—4 lbs.	4/17; 4/25; 5/2; 6/15	Entire block
4	Benzene hexachloride —5 acres	Benzene hexachloride—3 lbs.; Sulfur—6 lbs.	4/16; 4/22; 5/1; 6/15	Entire block
5	Check—5 acres	None		

[1] Prepared by the Taylor Chemical Company, Aberdeen, North Carolina.
[2] Prepared by the Niagara Sprayer and Chemical Company.

Records were secured of the number of curculios entering Orchards 1, 2, and 5 (Tables 4 and 5), and occasional records were taken on Orchards 3 and 4. Counts of curculios were obtained by jarring them onto a sheet under the tree and counting the number collected. A portion of each of 5 trees was jarred each time the records were taken from which the average number of curculios per tree was

computed. In tables 4 and 5 (Orchards 1, 2, and 5) it will be noted that the lead and benzene hexachloride blocks started the 1947 season with approximately the same population and that the population of curculios remained about the same in all blocks, with the exception of the checks, throughout the season. The check in each table represents Orchard 5 which was not sprayed. Sufficient records were taken in Orchards 3 and 4 to show that populations were similar in each block of both orchards at the beginning of the season.

Table 4.—A comparison of acid lead arsenate and benzene hexachloride in curculio control. Orchard No. 1.

	Average Number Curculio per Tree				
	Acid Lead Arsenate		Benzene Hexachloride		
Date	Edge	10th Row	Edge	10th Row	Check
4- 9-47	33	—	36	5	12
4-18-47	9	3	12	12	14
4-25-47	12	3	24	3	52
4-29-47	3	1	4	4	22
5- 6-47	3	½	0	1	16
5-16-47	2	1	½	½	10
6-18-47	2	½	0	0	2
6-24-47	1	½	0	½	—
7- 2-47	0	0	1	0	—
7-10-47	½	0	0	0	—
7-18-47	½	½	½	1	0
7-22-47	0	0	0	0	1
9-17-47	0	0	0	0	6

Table 5.—A comparison of basic lead arsenate and benzene hexachloride in curculio control. Orchard No. 2.

	Average Number Curculio per Tree				
	Basic Lead Arsenate		Benzene Hexachloride		
Date	Edge	10th Row	Edge	10th Row	Check
4- 9-47	4	—	5	—	12
4-18-47	5	2	4	7	14
4-24-47	4	3	7	1	52
4-29-47	6	2	5	½	22
5- 6-47	1	1	2	½	16
5-16-47	1	½	2	0	10
6-24-47	0	0	0	0	2
7- 2-47	½	0	1	0	—

From fig. 2 it will be noted that the percentage of wormy drops was two to four times as great in the lead blocks as in the benzene hexachloride blocks even though the adult curculio populations were approximately equal. The number of wormy drops was usually greater along the outside row than they were 10 rows in from the edge.

WORMY FRUIT AT HARVEST.—Though 25 acres of Orchard 1 did not receive a month-before-harvest spray, there was never more than 2 per cent wormy fruit found in any sample of peaches. The percentage of wormy fruit for the entire harvest period averaged less than 1 per cent in the benzene hexachloride blocks and only 1.5 per cent in the lead block. Orchard 2 also had less than 1 per cent. Orchard 3 had 1 per cent wormy fruit in the benzene hexachloride-treated area and 6 per cent in the lead-treated area. Orchard 4 had less than 1 per cent in both blocks. The check orchard (5) had 60 per cent wormy fruit. Orchard 3 had more wormy fruit at harvest than the other sprayed orchards probably because drops were not picked up in this orchard.

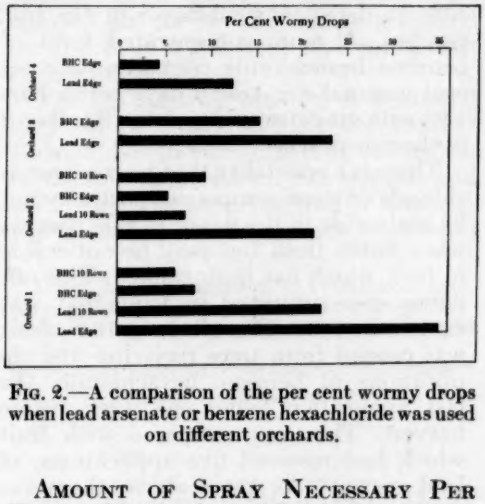

FIG. 2.—A comparison of the per cent wormy drops when lead arsenate or benzene hexachloride was used on different orchards.

AMOUNT OF SPRAY NECESSARY PER TREE.—Benzene hexachloride proved very effective in controlling the plum curculio during the 1947 season when the growers used 3 to 4 gallons of spray per tree. This amount of spray was sufficient thoroughly to drench the tree and cause a heavy enough drip to wet the soil under the tree. Some of the grower did not spray heavily. This is probably the reason they were not satisfied with results from benzene hexachloride. From field observations it appears necessary to have the soil as well as the tree wet thoroughly with benzene hexachloride spray. The curculios leave the tree by crawling down the limbs and the trunk to the ground soon after it is sprayed. If the ground also has sufficient spray material, the curculios will be forced to remain in contact with the poison, whereas if insufficient material is

applied, they are able to move to the ground and out of the effective zone of spray material. The material is effective on the ground because it seems to serve as both a contact and a fumigant against the plum curculio.

FLAVORING OF FRUIT.—During the 1946 season there was considerable controversy as to the effect of benzene hexachloride on the flavor of peaches. It was noted that benzene hexachloride caused the peaches to have a musty flavor if used too near harvest. The benzene hexachloride on the market in 1947 did not have as much musty odor and it was hoped that it would not taint the fruit as in 1946. To check this point, some trees were sprayed within 4 or 5 days before harvest, and in most cases it was not possible to detect any off-flavor in the ripe peaches. A more concentrated form of benzene hexachloride containing 25 per cent gamma[1] was used 2 days before harvest without causing any detectible flavor in the ripe peaches.

There is a possibility that benzene hexachloride or some component part may not be noticeable in the flavor of ripe peaches when eaten fresh but may be noticeable in fruit which has been canned. This off-flavor was suspected in fruit that was canned in 1946. Therefore, in 1947, fruit was canned from trees receiving five applications of benzene hexachloride, the last application being one week before harvest. This was compared with fruit which had received five applications. of lead arsenate. As stated above, there was no detectible difference in the flavor of the ripe fruit at harvest but after canning the fruit from the benzene hexachloride block was slightly off-flavor. This flavor can best be described as being a mild almond flavor similar to that obtained when peach kernels are included with fruit in the normal process of canning.

HEXAETHYL TETRAPHOSPHATE.—Hexaethyl tetraphosphate was originally discovered in Germany and the proprietary product containing this material was known as *Bladan*. The material first appeared in the United States late in 1945. In 1946 several of the insecticide companies were manufacturing small quantities, and experimental work indicated promise in the control of aphids and mites.

[1] Furnished by the California Spray Chemical Company under the trade name of *Isotox*.

In April, 1947, some of this material was obtained[2] and preliminary tests against the plum curculio in the laboratory were very promising. On April 25 a formulation containing 50 per cent hexaethyl tetraphosphate[3] diluted at the rate of two quarts to four and one-half gallons of water was applied to some peach trees with a TIFA[4] fog machine. This was applied with a large particle size (about 40 microns) at the rate of approximately 3 gallons of diluted mixture per acre. This is equivalent to approximately three pints 100 per cent hexaethyl tetraphosphate per acre. Before the trees were treated they had an average infestation of 16 curculios per tree. Twelve hours after treating, 15 trees were jarred without finding any living curculios.

Table 6.—Summary of tests with 100 per cent hexaethyl tetraphosphate on peaches April 25 to May 8, 1947.

METHOD OF APPLICATION	DATE TREATED	APPROXIMATE AMOUNT HEXAETHYL TETRAPHOSPHATE PER ACRE	AVERAGE NO. CURCULIOS PER TREE	
			Before Treating	12 to 24 Hours After Treating
Fog machine	4/25/47	1500 cc.	16	0
Airplane[1]	4/27/47	250 cc.	?	4
Airplane	4/28/47	250 cc.	?	1.5
Fog machine	4/29/47	800 cc.	30	6
Fog machine	4/30/47	1000 cc.	20	3
Airplane	5/ 1/47	750 cc.	27	9
Fog machine	5/ 1/47	1600 cc.	14	0
Airplane	5/ 3/47	750 cc.	12	6
Airplane	5/ 6/47	750 cc.	16	6
Airplane	5/ 6/47	1000 cc.	3	1
Fog machine	5/ 6/47	500 cc.	12	6
Boom on ground machine	5/ 8/47	1000 cc.[2]	8	4
Buffalo Turbine	5/ 8/47	1000 cc.	8	3.5
2-Nozzle Hand Gun	5/ 8/47	1000 cc.[2]	18	3
Airplane	5/16/47	750 cc.	?	3
Airplane	5/16/47	1500 cc.	18	0

[1] Airplane had fog-type applicator.
[2] Material diluted 1–800.

Hexaethyl tetraphosphate applied by airplane with a fog type applicator[5] gave results quite similar to those obtained with the fog machine. Tests were also conducted in the field using hexaethyl tetraphosphate with a conventional ground machine with 2-nozzle guns and also with

[2] Furnished by the Monsanto Chemical Company.
[3] Prepared by the Organic Chemicals Corporation, Frederick, Maryland.
[4] Todd Insecticidal Fog Applicators.
[5] The United Crop Dusters, Candor, North Carolina.

a *Buffalo Turbine*. The results of some of these tests are tabulated in Table 6 and indicate that for satisfactory control of the plum curculio it is necessary to use approximately 1500 cc of 100 per cent hexaethyl tetraphosphate per acre regardless of the way it is applied.

Hexaethyl tetraphosphate is known to be very injurious to warm-blooded animals, and several reports were received of individuals feeling a tightness in breathing or a constriction in the chest when they came in contact with vapors from the fog machine or airplane.

Although the material will kill the plum curculio, it is doubtful that it will ever have an important role in a curculio control program. The toxic effects are immediate with no residual value, and plum curculios coming into the orchard the day after application could attack the fruit. Moreover, the material may injure the foliage. For these reasons it is unlikely that it will be used in the plum curculio control program in North Carolina.

CHLORINATED CAMPHENE.[1]—On April 17, 1947, an experiment comparing the effectiveness of a chlorinated camphene (4 pounds of 29 per cent material per 100 gallons of water) and benzene hexachloride (6 per cent gamma) at two and four pounds per 100 gallons was set up in an orchard at Candor, North Carolina. Eight rows next to the woods were sprayed with chlorinated camphene, the next two with benzene hexachloride (2 pounds), and four rows with benzene hexachloride (four pounds). The four rows beyond the benzene hexachloride plot were not sprayed. Spraying was done with a power sprayer using 3-nozzle brooms at about 400 pounds' pressure.

Before spraying, the average number of curculios per tree was fairly uniform as indicated in table 7. However, the population dropped very rapidly where benzene hexachloride was used at the rate of 4 pounds per 100 gallons. The chlorinated camphene decreased the population as much as, or more than, the 4 poun s of benznee hexachloride, but required a slightly longer time. Benzene hexachloride at 2 pounds per 100 gallons did not reduce the population as much nor as fast as did the benzene hexachloride at four pounds, or the chlorinated camphene.

[1] Chlorinated camphene was supplied by Hercules Powder Company.

FIG. 3.—Cryolite injury on small peaches which received a delayed petal fall spray.

TREE INJURY.—No injury was observed on any trees sprayed with benzene hexachloride even though some trees were sprayed six times. The foliage remained on the trees until frost and retained a dark green color

Peaches sprayed with cryolite showed very severe injury on May 26, 1947 at Raleigh, North Carolina, after having received four applications. The weather had been very dry until the fourth spray at which time it turned stormy for several days. The leaves on these trees showed considerable burning especially along the margins. Golden Jubilee peaches which ripened about July 12 were a complete loss because they turned soft and mushy and did not have any flavor. This was definitely cryolite injury because adjacent trees sprayed with benzene hexachloride, lead arsenate, or chlorinated camphene did not show these symptoms. On October 3, there was less than 10 per cent defoliation on the cryolite sprayed trees, but the leaves were yellowish to orange whereas

Table 7.—A comparison of chlorinated camphene with 2 and 4 pounds of benzene hexachloride (6 per cent gamma). Trees sprayed 4-17-47.

	AVERAGE NUMBER CURCULIOS PER TREE			
		Benzene Hexachloride		
DATE	Chlorinated Camphene	2 Lbs.	4 lbs.	Check
4-17-47	22	20	18	—
4-18-47	19	16	3	—
4-21-47	3	8	2	16
4-25-47	1	6	2	12
4-29-47	4	7	6	—

the leaves on the benzene hexachloride and chlorinated camphene blocks were dark green. Some of the yellowish-orange color may have been caused by an infestation of mites[1] which was especially heavy on the cryolite-sprayed trees.

Cryolite also caused some injury to peaches where it was used only as a petal fall spray. The injury first appeared as a burning of the tip of the fruit. This retarded the growth of the tip of the peach, and at harvest time they appeared somewhat flattened or even dimpled at the tip. Figure 3 shows some of the variation in cryolite injury on the small fruits.

Trees at Raleigh which received five applications of acid lead arsenate were completely defoliated by October 3. A few

FIG. 4.—Hexaethyl tetraphosphate injury on peach leaves.

new leaves were growing at the terminals and a few blossoms were open on the tree. Severe injury could also be seen on the wood. Trees in the Sand Hills which received only one application of acid lead arsenate June 20 (month before harvest spray) showed nearly as much injury as trees which had received the usual lead arsenate sprays throughout the season.

Trees which received five applications of basic lead arsenate were about 75 per cent defoliated on October 3. Injury to the wood was not nearly as severe as on the trees receiving the acid lead sprays. Commercial orchards which were sprayed with basic lead arsenate also showed less injury than commercial orchards sprayed with acid lead arsenate.

The injury from hexaethyl tetraphosphate first appears on leaves and fruit as minute reddish or purplish spots. These spots may vary from pin points to the size of a match head. On leaves the center tends to drop out of the larger spots giving the leaves a shot-hole appearance, figure 4. Where the material was applied by the fog machine the injury showed up most severely on the leaves which were nearest to the nozzles. In the case of airplane application most of the injury occurred on the topmost leaves. With ground machine application, the spots occurred throughout the tree. It was also observed that the injury was more severe and more noticeable on weak and poorly cared for trees than on vigorous and well cared for trees.

Injury from chlorinated camphene was observed on the leaves four days after the trees were sprayed at Candor, North Carolina. It appeared as a burning especially around the marging of the leaves. A general yellowing of the leaves was also observed. Within a week after application, many of the leaves had dropped off. This same material was used in sprays at Raleigh but with wettable sulfur included at the rate of 6 pounds per 100 gallons. As no injury was apparent on these trees, additional trees were sprayed at Raleigh using chlorinated camphene without sulfur and the same type of injury appeared as was observed on trees at Candor.

At Raleigh, the chlorinated camphene was used at the rate of 4 and 8 pounds of the 29 per cent material per 100 gallons plus 6 pounds of wettable sulfur. Starting with the petal fall spray four applications were made at weekly intervals and a fifth application was applied one month before harvest. No injury was observed on any trees sprayed with the chlorinated camphene where wettable sulfur was included and they retained their foliage until frost. At harvest time the fruit of Golden

[1] *Paratetranychus pilosus* (C. & F.) Det. by Dr. E. W. Baker.

Jubilee, Hiley Belle, Belle of Georgia, and Elberta appeared to be in excellent condition.

SUMMARY.—The majority of the plum curculios hibernate in the debris within 50 feet of the edge of the woods surrounding the peach orchards. Burning of this debris during the winter kills many of the curculios, but apparently it does not kill enough to permit any reduction in the amount of spraying that is necessary.

Benzene hexachloride gave good control of the plum curculio when used at 4 pounds (6 per cent gamma) per 100 gallons and 3 to 4 gallons of spray per tree. One 25-acre block was cleaned up so thoroughly that the 1-month-before-harvest spray was not necessary. Benzene hexachloride caused an off-flavor in canned peaches (5 applications, last application one week before harvest). However, no off-flavor was detected in the fresh fruit.

Chlorinated camphene shows promise in controlling plum curculios but wettable sulfur must be used as a safener with this material.

Cryolite, lead arsenate, and hexaethyl tetraphosphate caused injury to the peach trees, leaves, and fruit.

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Control of Plum Curculio with Benzene Hexachloride[1]

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General interest on the part of Delaware farmers in the insecticidal possibilities of benzene hexachloride, stimulated by the encouraging findings reported during 1946, prompted studies in 1947 to establish better its place among recently-developed toxicants of potential value as controls for many pests damaging fruit and vegetable crops. This paper deals only with the results of tests on peaches involving the plum curculio, *Conotrachelus nenuphar* (Hbst.).

This insect, some 20 years ago, was responsible for heavy losses in Delaware. Subsequently, by reason of the widespread application of several control measures which supplement spraying, its population was greatly reduced and codling moth, *Carpocapsa pomonella* (L.), became, then, the chief problem confronting local growers. Now, after a period of decidedly less intensive effort against curculio and with DDT apparently an adequate solution in the case of codling moth, the pendulum of concern has swung again to curculio. Thus, it happened that in the spring of 1947 the following question was very frequently encountered—Will benzene hexachloride prove effective against curculio? The tests reported herein were an attempt to supply an answer.

EXPERIMENTAL ORCHARD.—A middle-aged block of peaches in a commercial planting in northern New Castle County was made available[3] for this work. It was rectangular in shape, 8 by 23 rows; the trees had been set 22′ by 22′; the tree spread, for 48 trees measured on June 5, averaged 20′ by 18′; and it included three rows of the Georgia Belle and five rows of the White Hale variety. The cooperating orchardist, with intent to reduce arsenical injury, has regularly used basic lead arsenate for curculio control. Accordingly, three plots were established across the

Eastern Branch Program.

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[3] By Mr. J. C. Webster.

two varieties—the first (11 by 8 rows), to be treated with basic lead arsenate; the second (6 by 8 rows; center), to be treated with benzene hexachloride[1]; and the third (6 by 8 rows), to be treated with acid lead arsenate. This arrangement provided a direct comparison of these three insecticides. Possible mid-season treatments against Oriental fruit moth were purposely omitted for the sake of clarity in results. The spray program is set forth in detail in table 1. The sprayer was a 500-gallon, power-take-off unit. A single-nozzle gun, operated from the tractor, was used to cover the lower parts of the trees and an eight-nozzle broom, from the tank, the tops. Applications, by the usual farm labor, were made from both sides of the rows.

Table 1.—Spray treatments, Georgie Belle and White Hale block, J. C. Webster peach orchard, near Wilmington, Delaware, 1947

SPRAY	BASIC LEAD ARSENATE[1]	ACID LEAD ARSENATE[2]	BENZENE HEXACHLORIDE[3]
Dormant	10 gals.[4] Liquid Lime Sulfur (entire block)		
Pre-blossom	12 lbs. Flotation Sulfur (entire block)		
Petal Fall	(recommended, generally, but omitted by this grower)		
Shuck (May 19)	8 lbs. Spray Lime 4 lbs. Lead Arsenate 10 lbs. Flotation Sulfur 0.5 lb. Sticker[6]	2 lbs. Zinc Sulphate[5] 8 lbs. Spray Lime 2 lbs. Lead Arsenate 10 lbs. Flotation Sulfur 0.5 lb. Sticker	3 lbs. Benzene Hexachloride 10 lbs. Flotation Sulfur 0.5 lb. Sticker
7 Days Later (May 26)			3 lbs. Benzene Hexachloride
14 Days Later (June 2)	8 lbs. Spray Lime 4 lbs. Lead Arsenate 10 lbs. Flotation Sulfur	2 lbs. Zinc Sulphate 8 lbs. Spray Lime 2 lbs. Lead Arsenate 10 lbs. Flotation Sulfur	3 lbs. Benzene Hexachloride 10 lbs. Flotation Sulfur
(followed by three sulfur sprays over entire block for protection of maturing crop from brown rot)			

[1] Basic lead arsenate—Niagara.
[2] Acid lead arsenate—Grasselli.
[3] *Lezone*—duPont (Grasselli) benzene hexachloride.
[4] All rates per 100 gallons of water.
[5] Monohydrated zinc sulphate—Southern States.
[6] *Spraysoy*—a soybean product of the Glidden Co.

RECORDS.—Control data, as summarized in table 2, were recorded as follows: (1) 18 White Hale trees in the same row, six in each plot, were jarred on May 28, June 5, 13, 20, and 27 to collect overwintered adult curculios; (2) random collections of 300 dropped peaches, 100 in each plot, were made on June 2, 5, 13, 20, and 27 to determine infestation by first-brood curculio grubs; (3) leaf-fall counts for 9 square feet beneath 48 trees, 16 in each plot, were taken on June 13, 27, July 3, 10, and 17; (4) the extent of twig injury by first-brood Oriental fruit moth, *Grapholitha molesta* (Busck), larvae was noted for the same 48 trees, 16 in each plot, on June 13; and (5) harvest records for six Georgia Belle and for six White Hale trees in each plot (total of 36 trees) were completed from August 28 to September 9, inclusive.

DISCUSSION.—It will be noted first, in table 2 that a total of 505 overwintered adult curculios were collected by jarring in the basic lead arsenate plot; 245, in the acid lead arsenate plot; and but 116, in the benzene hexachloride plot. The population in the case of benzene hexachloride was 53 per cent less than that with acid lead and 77 per cent less than that with basic lead. The numbers of the insect were consistently high week after week (data in lower third of table) in the portion of the block treated with basic lead and consistently negligible in the central section sprayed with benzene hexachloride.

Infestation of small peaches appears to

[1] duPont Company product, a "50% hexachlorocyclohexane insecticide composition; gamma isomer of hexachlorocyclohexane, 6%; other isomers, 44%."

Table 2.—Summary of control data, J. C. Webster peach orchard, near Wilmington, Delaware, 1947, showing comparison of basic arsenate of lead, acid arsenate of lead and benzene hexachloride.

Items Compared		Basic Lead Arsenate	Acid Lead Arsenate	Benzene Hexachloride
Number, Curculios collected by jarring	Belle[1]			
	Hale[2]	505	245	116
	Both			
Per cent, dropped peaches infested by grubs	Belle			
	Hale			
	Both	78	56	1
Number, fallen leaves	Belle			
	Hale			
	Both	1,541	2,137	989
Number, twigs injured by first-brood Oriental fruit moth larvae	Belle			
	Hale			
	Both	177	73	56
Number peaches	Belle	6,536	9,091	9,782
	Hale	7,375	8,356	11,248
	Both	13,911	17,447	21,030
Number dropped fruits (pre-harvest)	Belle	1,703	1,078	2,193
	Hale	2,845	2,296	4,300
	Both	4,548	3,374	5,493
Per cent, dropped fruits (pre-harvest)	Belle	26.1	11.9	22.4
	Hale	38.6	27.5	38.2
	Both	32.7	19.3	30.9
Number, picked fruits	Belle	4,833	8,013	7,589
	Hale	4,530	6,060	6,948
	Both	9,363	14,073	14,537
Number, peaches per bushel	Belle	251	250	281
	Hale	179	190	221
	Both	215	220	251
Number, clean peaches in dropped and picked fruits	Belle	5,591	8,328	7,978
	Hale	5,026	7,044	7,598
	Both	10,617	15,372	15,576
Per cent, clean peaches in dropped and picked fruits	Belle	85.5	91.6	81.6
	Hale	68.1	83.4	67.5
	Both	76.3	88.1	74.1
Number, curculio-injured peaches in dropped and picked fruit	Belle	148	54	178
	Hale	111	152	193
	Both	259	206	371
Per cent, curculio-injured peaches in dropped and picked fruit	Belle	2.3	0.6	1.8
	Hale	1.5	1.8	1.7
	Both	1.9	1.2	1.8
Number, Oriental fruit moth-injured peaches in dropped and picked fruit	Belle	635	600	1,475
	Hale	1,426	700	2,102
	Both	2,061	1,300	3,577
Per cent, Oriental fruit moth-injured peaches in dropped and picked fruit	Belle	9.7	6.6	15.1
	Hale	19.3	8.4	18.7
	Both	14.8	7.5	17.0
Number, brown rot-injured peaches in dropped and picked fruit	Belle	180	124	199
	Hale	1,135	563	1,750
	Both	1,316	687	1,949
Per cent, brown rot-injured peaches in dropped and picked fruit	Belle	2.8	1.4	2.0
	Hale	15.4	6.7	15.6
	Both	9.5	3.9	9.3
Number curculio and Oriental fruit moth-injured peaches with brown rot	Belle	18	15	48
	Hale	334	103	395
	Both	352	118	443
Per cent curculio and oriental fruit moth-injured peaches with brown rot	Belle	4.0	4.0	4.5
	Hale	14.8	9.0	12.1
	Both	13.0	7.8	10.2

Jarring and Drop Examination Dates	Adults per Tree	Peach Drops Infested	Adults per Tree	Peach Drops Infested	Adults per Tree	Peach Drops Infested
	Number	Per Cent	Number	Per Cent	Number	Per Cent
May 28	23.2		6.4		0.0	
June 2		96		87		1
5	21.7	93	7.0	72	1.8	2
13	23.3	85	11.5	68	4.5	2
20	12.3	62	9.7	40	7.7	1
27	7.7	54	7.3	13	5.4	1
Average	17.4	78	8.4	56	4.0	1

[1] Belle of Georgia. [2] White Hale.

be directly correlated with adult abundance. As high as 78 per cent of all peaches which dropped during June in the basic lead plot, contained first-brood curculio grubs; 56 per cent, in the acid lead plot; and but 1 per cent in the benzene hexachloride plot. On June 5, when the heaviest drop was taking place, the percentages

were 93, 72, and 2, respectively. This amounts to almost complete control with benzene hexachloride. Basic lead arsenate (at 4 lbs. per 100 gals.) was definitely inferior to acid lead arsenate (at 2 lbs per 100 gals.).

The foliage situation with benzene hexachloride was very satisfactory throughout the summer; leaf-fall was 36 per cent less than with basic lead and 54 per cent less than with acid lead.

The influence of these treatments on the activity of first-brood Oriental fruit moth larvae shows the same general trend as observed in curculio control. A total of 177 injured twigs (11.1 per tree) was recorded for basic lead; 73 (4.6 per tree), for acid lead; and 56 (3.5 per tree) for benzene hexachloride. These figures are of doubtful significance, however, by reason of the light early-season infestation and, furthermore, they may be viewed as inconsistent with the harvest results.

As might be expected from the curculio-control data, the 12 count trees in the benzene hexachloride plot produced a crop totalling 21,030 peaches; those in the acid lead plot, 17,447 peaches; and those in the basic lead plot, but 13,911 peaches.

Weather conditions in 1947 were such as to delay maturity about 10 days. As a result, there was a heavy pre-harvest drop, opportunity for greater damage by late Oriental fruit moth larvae, and considerable brown rot infection—more pronounced, naturally, in the case of White Hale which was picked last.

Irrespective of varieties (and limiting the discussion at this point to benzene hexachloride and acid lead arsenate, since basic lead arsenate is neither recommended nor commonly used on peaches in Delaware), the following conclusions may be drawn from the harvest data: (1) the pre-harvest drop was much greater with benzene hexachloride (31 per cent *vs.* 19 per cent); (2) the peaches were somewhat smaller with benzene hexachloride (251 *vs.* 220 per bushel); (3) the amount of clean fruit was less with benzene hexachloride (74 per cent *vs.* 88 per cent); (4) there was no difference between benzene hexachloride and acid lead in the percentage of curculio-injured peaches (did not exceed 2 per cent in either case); (5) the loss from Oriental fruit moth was more severe with benzene hexachloride (17 per cent *vs.* 7.5 per cent); and (6) brown rot infection was higher with benzene hexachloride (9 per cent *vs.* 4 per cent). It is worthy of note here that only 11 per cent (average for the block) of the recorded brown rot was associated with injury by curculio and Oriental fruit moth.

SUMMARY.—In tests conducted during 1947 in an 8-year-old planting of Georgia Belle and White Hale peaches in northern Delaware, basic lead arsenate, acid lead arsenate and benzene hexachloride were compared for control of plum curculio on the basis of three sprays applied on May 19, May 26, and June 2. The population of overwintered adult curculios in the case of benzene hexachloride was 53 per cent less than that with acid lead and 77 per cent less than that with basic lead.

Only one per cent of all peaches, which dropped during June in the benzene hexachloride plot, contained first-brood curculio grubs, whereas a 56 per cent infestation was recorded in the acid lead plot and as high as 78 per cent in the basic lead plot.

The foliage situation with benzene hexachloride was very satisfactory throughout the season; leaf-fall was 36 per cent less than with basic lead and 54 per cent less than with acid lead.

In full agreement with the curculio-control data, the count trees of the benzene hexachloride plot produced a crop totalling 21,030 peaches; those in the acid lead plot, 17,447 peaches; and those in the basic lead plot, but 13,911 peaches.

However, weather conditions were such as to delay maturity about 10 days. As a result, there was a heavy pre-harvest drop, opportunity for greater damage by late Oriental fruit moth larvae, and, considerable brown rot infection—more pronounced in the case of White Hale which was picked last.

The harvested crop, as affected by the factors just stated, showed 88 per cent of the peaches uninjured by insects and free from disease in the case of acid lead arsenate; 76 per cent, in the case of basic lead arsenate; and 74 per cent in the case of benzene hexachloride. In other words, the considerable balance established in favor of benzene hexachloride early in the season was more than offset by complications directly attributable to delayed ripening of the varieties in question.

Benzene Hexachloride and DDT to Control Plum Curculio

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The work reported herein consists of field and laboratory experiments with benzene hexachloride as a spray, and field and laboratory applications of benzene hexachloride and DDT to soil, for controlling the plum curculio. The study was conducted because of the urgent need for a satisfactory control of the plum curculio on peaches and the promising results which were obtained in early experiments by Bobb (1946) and others[2] with benzene hexachloride for controlling this insect.

The benzene hexachloride treatments in the spray tests were prepared from a wettable commercial formulation stated to contain 6 per cent of gamma isomer and 44 per cent of other isomers, and for the soil applications they were prepared from a dust reported to contain 10 per cent of concentrate (all isomers) and approximately 3 per cent of gamma isomer. A stock material containing 25 per cent wettable DDT dust was used in making the DDT soil treatments.

FIELD SPRAY EXPERIMENT.—An experiment for control of the plum curculio was conducted in a peach orchard near Cloverdale, Virginia. It was designed to compare the effectiveness of benzene hexachloride, at different concentrations and from different numbers of applications, with the standard acid lead arsenate spray. The treatments applied are shown in table 1. A plot size of 2 trees was employed and the treatments were replicated 5 times in a latin square design. The design provided for buffer strips 1 or 2 trees wide on all sides of the treated area and 1 tree wide between rows and columns. These buffer trees were sprayed with 4 pounds of basic lead arsenate and 4 pounds of hydrated lime per 100 gallons of spray. All sprays were applied from a 2-nozle spray gun connected with a power sprayer. The results were determined by picking up the drop peaches at intervals of 4 to 10 days and placing them in a basket suspended over a funnel leading into a fruit jar. Counts were made of the larvae after they emerged from the fruit and fell into the jars.[2]

The results are shown in table 1. The data were analyzed by the analysis of variance after first being subjected to a mathematical transformation. The average number of worms obtained from 4 applications of benzene hexachloride at a rate of 0.05 pound of gamma isomer per 100 gallons of spray was significantly less ($P<.05$) than the average number obtained from 3 applications of the standard acid lead arsenate spray. As the concentrations of benzene hexachloride were increased the resulting reductions in numbers of worms followed a definite linear trend downward, with the difference between the concentrations of 0.05 and 0.20 pound of gamma isomer per 100 gallons of spray being greater than required for significance at a probability of 5 per cent. There was no significant difference ($P>.05$) between 2 and 4 applications of benzene hexachloride.

Although the basic lead arsenate treatment was not included as a regular plot in the experimental design, the number of worms obtained from 10 trees treated with this material was determined in the same way as described for the planned treatments. An average of 49.0 worms per tree was obtained as compared to an average per tree of 26.8 for the acid lead arsenate treatment.

LABORATORY SPRAY EXPERIMENT.—The purpose of the laboratory spray test was to compare the effectiveness of the standard acid lead arsenate spray with different rates of benzene hexachloride in killing the adults of the plum curculio. One treatment consisted of 2 pounds of acid lead arsenate, 6 pounds of hydrated lime, and 3 pounds of flake zinc sulphate per 100 gallons; the other 5 treatments consisted of benzene hexachloride at concentrations of 0.05, 0.10, 0.20, 0.40 and 0.80 pound of gamma isomer, with 1 pint of spreader-sticker, per 100 gallons.

All sprays were applied with a 4-gallon,

Eastern Branch.

[1] The assistance of Miss N. V. Sibold in one phase of the study is acknowledged.

[2] J. O. Pepper and C. F. Smith in the Proceedings of the 23rd Annual Meeting of the Cumberland-Shenandoah Fruit Worker's Conference, 1946.

compressed-air sprayer. The procedure consisted of spraying peach twigs with each of the treatments until the foliage was thoroughly wet, allowing the twigs to dry, and then placing them in a 11 by 11 by 14-inch cage. The cut ends of the twigs were kept in water to ensure the leaves remaining in good condition during the period of observation. Twenty-five adult curculios were introduced into each cage, and observations were made at the end of 1, 2, 4, and 8 days to determine the curculio mortality. The criterion of mortality was failure to exhibit notion of any part of the body.

The results are shown in figures 1 and 2. In figure 1 the net mortality was determined by use of Abbott's formula (Abbot 1935) and the time-mortality line was fitted by eye. In figure 2 adjustments were made for natural mortality by use of weighting coefficients (Finney 1944) and the dosage-mortality lines were fitted to the points by the method of least squares (Bliss 1925). The amounts of benzene hexachloride per 100 gallons calculated to kill 50 per cent of the adult curculios at the end of 2-, 4-, and 8-day intervals, respectively, were as follows: 0.320, 0.233, and 0.174 pound of gamma isomer. Similarly, from 0.779 to 0.816 pound of gamma isomer per 100 gallons was the amount calculated to kill 95 per cent of the beetles within a period of 4 to 8 days.

Table 1.—Results of the application of different sprays for control of the plum curculio on peaches, Cloverdale, Virginia, 1947.

Material and Amount per 100 gallons[1]	Dates of Application	Number of Replication	Peaches per Tree (Average of 10 Trees)		Average Worms per Tree	
			Drops	On Tree[2]	Number	Log. (Y+1)
Lead arsenate, 2 pounds Hydrated lime, 6 pounds Flake zinc sulphate, 3 pounds	April 22 April 29 May 12	5	259.3	835.0	26.8	1.3343
Benzene hexachloride, 0.05 pound gamma isomer	April 22 April 29 May 5 May 14	5	244.0	1010.0	7.8	0.8488
Benzene hexachloride, 0.10 pound gamma isomer	April 22 April 29 May 5 May 14	5	264.6	1025.0	5.5	0.6098
Benzene hexachloride, 0.20 pound gamma isomer	April 22 April 29 May 5 May 14	5	251.1	1025.0	2.7	0.2924
Benzene hexachloride, 0.20 pound gamma isomer	April 29 May 14	5	304.2	1055.0	4.6	0.6754

Difference, expressed as log. (Y+1), required for significance:
At odds of 19 to 1 = .4268.
At odds of 99 to 1 = .5982.

[1] Five pounds of wettable sulfur was included in the last application of all treatments, and 1 pint of spreader-sticker was included in all other applications of the benzene hexachloride treatments.
[2] Estimated after making counts of the number of peaches on several trees of different sizes.

Fewer than 50 per cent of the adult curculios were killed within a period of 8 days by the standard acid lead arsenate spray.

SOIL TREATMENTS.—The effectiveness of soil treatments with benzene hexachloride and DDT in controlling the plum curculio was tested both in the field and in the laboratory. For the field experiment each of the treatments was mixed with the top 2 to 3 inches of soil in an area 4 feet by 4 feet under a peach tree. Newly emerged larvae were introduced into a cage securely held in contact with this soil and with a strip of screen inserted into the soil under the edges to prevent the curculios from leaving the area under-

neath the cages. As soon as adults began to emerge in the cages they were periodically counted and removed until emergence ceased. The procedure was similar for the laboratory experiment except that 10 by 10-inch trays of soil with a cage over each were used.

The results are shown in table 2. The data were not analyzed statistically because of the unequal numbers of replicates. The only treatment which gave sufficient control to be at all promising was the benzene hexachloride at a rate of 1.0 pound of gamma isomer per acre.

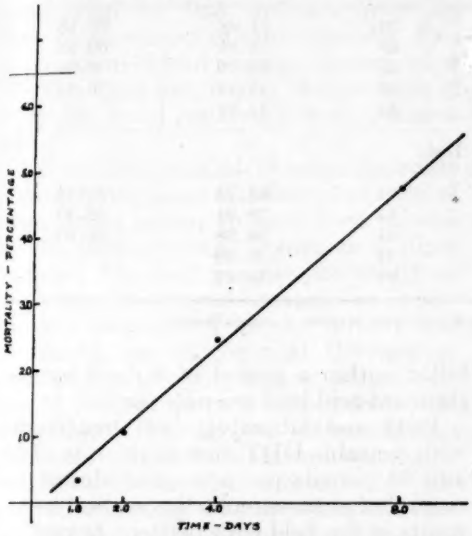

FIG. 1.—Laboratory toxicity of the standard acid lead arsenate spray to plum curculio adults. Six tests averaging 20 insects each were made in determining each point. The line was fitted to the points by eye.

DISCUSSION.—Bobb (1946) reported the minimum effective dosages of benzene hexachloride for controlling plum curculio adults in the spring and in the fall, respectively, as being 0.11 and 0.19 pound of gamma isomer per 100 gallons. The work of Snapp (1947) indicated that at least 0.10 pound of gamma isomer of benzene hexachloride per 100 gallons of spray is needed to effectively control the plum curculio. The results of the orchard spray experiment reported herein would also indicate that considerable reduction in number of worms could be obtained from 4 applications of a spray containing from 0.10 to 0.20 pound of gamma isomer per 100 gallons. However, these data should be interpreted with caution. It is likely that sprays containing moderate concentrations of benzene hexachloride kill some of the adult plum curculios and some of the larvae in the fruit; but when small areas are treated, it is also probable

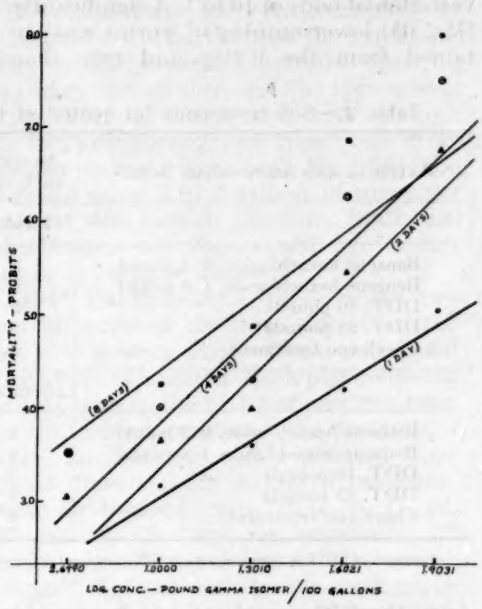

FIG. 2.—Laboratory toxicity of benzene hexachloride to plum curculio adults. A total of 43 to 50 insects in 2 tests were used in determining the points for the lowest and highest concentrations. Each of the points for the other concentrations was determined from 4 tests using a total of 86 to 98 insects.

that some of the adults migrate to adjacent untreated trees because of the apparent repellent action of benzene hexachloride. Therefore, the performance of this material when applied to trees in a large area should be determined before any conclusions are drawn as to its effectiveness in controlling the plum curculio on peaches.

More accurate information relative to the toxicity of benzene hexachloride to adult curculios can perhaps be obtained from the results of the laboratory spray experiment. These data indicate that a minimum of 0.233 and 0.78 pound of gamma isomer per 100 gallons of spray, respectively, are required to kill 50 and 95 per cent of the beetles within a 4-day period.

SUMMARY.—In an adequately replicated orchard experiment 4 applications of benzene hexachloride spray at concentrations of 0.05, 0.10, and 0.20 pound of

gamma isomer per 100 gallons each gave a greater reduction in number of plum curculio larvae, as compared to 3 applications of the standard acid lead arsenate spray, than could be attributed to chance variation at odds of 19 to 1. A significantly ($P<.05$) lower number of worms was obtained from the 0.20-pound rate than from the 0.05-pound rate, each receiving 4 applications, but there was less difference between 2 and 4 applications of 0.20 pound of gamma isomer per 100 gallons than required for significance at a probability of 5 per cent.

The results are presented of laboratory cage experiments conducted to determine the toxicity of various concentrations of benzene hexachloride, and the standard acid lead arsenate spray, to plum curculio adults within different periods of time. The amounts of benzene hexachloride calculated to kill 50 per cent of the adults within 2-, 4-, and 8-day periods, respectively, were 0.320, 0.233, and 0.174 pound of gamma isomer per 100 gallons of spray. From 0.779 to 0.816 pound of gamma isomer per 100 gallons was the amount calculated to obtain 95 per cent mortality in 4 to 8 days. Less than 50 per cent were killed within a period of 8 days by the standard acid lead arsenate spray.

Table 2.—Soil treatments for control of the plum curculio. Blacksburg, Virginia, 1947.

Material and Amount per Acre*	Number of Cages	Larvae per Cage	Per Cent Mortality	Per Cent Control
Field Tests				
Benzene hexachloride, 0.5 pound	3	59	61.02	28.13
Benzene hexachloride, 1.0 pound	2	59	78.81	60.93
DDT, 10 pounds	3	59	45.76	0.00
DDT, 25 pounds	3	59	49.15	6.25
Check (no treatment)	2	59	45.76	—
Laboratory Tests				
Benzene hexachloride, 0.5 pound	3	64	68.75	38.46
Benzene hexachloride, 1.0 pound	2	64	78.91	58.47
DDT, 10 pounds	3	64	59.38	20.01
DDT, 25 pounds	2	64	46.09	—
Check (no treatment)	2	64	49.22	—

* Amounts of DDT in terms of actual DDT; amounts of benzene hexachloride in terms of gamma isomer.

Field and laboratory soil treatments with wettable DDT dust at the rate of 10 and 25 pounds per acre gave almost no control of plum curculio larvae. Soil treatments in the field with benzene hexachloride at rates of 0.5 and 1.0 pound of gamma isomer per acre gave 28.1 and 60.9 per cent control. Soil treatments in the laboratory with benzene hexachloride at these same rates gave 38.5 and 58.5 per cent control.

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Some Organic Insecticides for Control of Plum Curculio on Peaches[1]

J. E. DEWEY[2] and J. D. VANGELUWE[3,4]

Lead arsenate has been recommended many years for the control of plum curculio on peaches (Crosby *et al.* 1929). One application has been the standard treatment in New York State for light to moderate infestations; while two applications have been used in the more heavily infested orchards (Crosby *et al.* 1941). It has been noted by the writers during the past four years, however, that one application of lead arsenate provided little or no control of plum curculio. Two applications of lead arsenate, though more effective than one, nearly always resulted in severe wood cankering from arsenical injury.

Severe dropping of peaches generally occurs during June and July, and most of these drops appear to have been injured by the feeding or egg deposition of plum curculio. Dropped peaches are nearly as numerous in sprayed orchards as in unsprayed orchards. With the advent and increasing use of chemical thinning of peaches by spraying during bloom, the loss of fruit as drops resulting from curculio injury becomes of increasing importance, whether the larvae mature or not. With these points and with the possible effectiveness of benzene hexachloride against the plum curculio in mind, an experiment was started in 1946 to determine the efficiency of this material as compared with lead arsenate. The trial of benzene, hexachloride[5] was continued in 1947. In addition, commercial formulations of chlordan,[6] chlorinated camphene,[7] and parathion were tested for the control of this pest.

A 12 acre, 8 year old, Elberta peach orchard having a history of severe curculio damage was selected in the Warwick Valley of southern Orange County as the site for the experiments in 1946 and 1947. The orchard was bordered completely on three sides and partially on the fourth side by woods. Standard orchard spraying equipment was used and the sprays were applied from the ground with a single nozzle spray gun. The trees were thoroughly covered from both the inside and outside using 4 to 5 gallons of spray per tree at 400 pounds pressure. Statistical significance was determined by the analysis of variance method.

1946 EXPERIMENT.—Trees in the two outside rows on the three sides bordered by woods were used. Weak and small trees were eliminated. Each plot consisted of two trees in the first row and two trees in the second row, and the treatments were randomized and replicated four times. Results were measured by examining all dropped fruits (June 16, 17, 18, 20, 24, & 25). and by examining 50 fruits selected at random before harvest (August 2) from each tree in each replicate for curculio feeding and egg deposition scars. A peach showing one scar or more was classified as infested.

The materials used in this experiment were commercial formulations of (1) a 31.6 per cent benzene hexachloride wettable powder containing 3.79 per cent gamma isomer; (2) a 50 per cent wettable powder containing 5 per cent gamma isomer and (3) acid lead arsenate. Treatment dates were as follows: Petal-fall stage on May 7, 35 per cent of the shucks off on May 22, 90 per cent of the shucks off on May 26, and a 10-day spray on June 5. Sixteen pounds of hydrated lime per 100 gallons of spray were included in the lead arsenate treatments, and 5 pounds of wettable sulfur per 100 gallons were applied for brown rot control with all treatments made on May 26, including the check plots. A list of the treatments and a summary of the results are presented in table 1.

The data in table 1 indicate the use of benzene hexachloride to be a promising method of controlling plum curculio based on the reduction of injured drops as compared to the drops occurring in the lead arsenate and unsprayed plots. Treat-

Eastern Branch Program.

[1] Results of a cooperative project between the Dept. of Entomology Cornell University and the Cooperative G. L. F. Exchange.

[2] Cornell University.

[3] Cooperative G. L. F. Exchange.

[4] The writers wish to acknowledge the assistance of M. J. Papai, Assistant County Agent of Orange County in the work reported in this paper.

[5] For supplying certain materials used in these studies the writers wish to express their appreciation to the following: American Cyanamid Company, E. I. du Pont de Nemours & Co., Inc., and California Spray Chemical Corp.

[6] *Synchlor.*

[7] *Phenatox.*

ment 7 which received 4 applications of benzene hexachloride was significantly superior to the lead arsenate and the untreated plots in the reduction of injured fruits at odds of 99 to 1.

Within the experiment an over-all range of 80 to 97 per cent of the drops were found to have been injured by plum curculio feeeing or egg laying scars. The percentage of injured drops varied in the benzene hexachloride-sprayed plots from 80 to 89, while a range of 92 to 97 per cent

The benzene hexachloride-treated trees appeared more vigorous and the leaves showed better color than the lead arsenate-sprayed trees. No injury to the foliage buds, tree wood, or fruits was apparent from the use of benzene hexachloride. There was a noticeably heavier infection of brown rot in the benzene hexachloride plots at harvest, but no counts were made. Benzene hexachloride did not affect the flavor of the ripe fruit eaten fresh.

1947 EXPERIMENT.—The outside four

Table 1.—Summary of results obtained in 1946 experiment for the control of plum curculio.

No.	AMOUNT AND MATERIAL PER 100 GALLONS	TIME OF APPLICATION	INJURED DROPS PER REPLICATE	PER CENT DROPS INJURED	PER CENT HARVEST FRUIT INJURED
	Benzene Hexachloride				
1	2 lbs. 3.79%	90% shuck-off	1017	88.9	23.0
2	3 lbs. 3.79%	90% shuck-off	692	88.5	18.6
3	4 lbs. 3.79%	90% shuck-off	625	89.0	20.0
4	3 lbs. 5%	90% shuck-off	878	80.2	16.0
5	3 lbs. 3.79%	35 & 90% shuck-off	706	84.1	19.4
6	3 lbs. 3.79%	Petal-fall, 35 & 90% shuck-off	733	82.9	14.4
7	3 lbs. 3.79%	Petal-fall, 35 & 90% shuck-off & 10-day spray	361	80.5	10.0
	Lead Arsenate				
8	2 lbs.	35 & 90% shuck-off	1133	93.8	11.6
9	2 lbs.	90% shuck-off	1308	92.6	14.9
10	Check		1205	96.7	24.9
Least significant difference		1 per cent	456	None	None

injury resulted in the lead arsenate and check plots. This indicates curculio injury to be a possible cause of losses resulting from dropped fruits. Injury as measured at harvest showed no significant differences. However, it is not an accurate means of determining injury since the benzene hexachloride trees had fewer drops and more fruits per tree at harvest than the lead arsenate treatments.

Applications made at the petal-fall, 35 per cent shuck-off, and 90 per cent shuck-off stages appear to be of less value than Treatment 7 which also received an additional application 10 days after shuck-off. Of the single applications made at the 90 per cent shuck-off stage, the 3 and 4-pound dosages of 3.79 per cent gzmma isomer and the 3-pound dosage of 5 per cent gamma isomer were noticeably better than 2 pounds of 3.79 gamma isomer. There was no significant difference between the untreated plots and those receiving one and two applications of lead arsenate.

rows on one of the wooded sides of the orchard were selected since they were found to be the most heavily infested in the 1946 experiment. Each plot consisted of one tree in each of the four rows, and was replicated in four randomized plots. Results were measured by counting and examining all drop fruits (June 24, 25, July 2 and 14), and all fruits thinned from the trees (July 14 and 15). All the fruits remaining on the tree were counted (Sept. 3 and 4), and harvest injury calculated by examining 50 fruits selected at random from each tree in each replicate (Sept. 5). In all the counts, a peach showing one or more egg-laying or feeding scars, was classified as infested. The results presented for this experiment include data taken from two replicates only, since heavy rains prevented the first and second drop counts from being made in the remaining two replicates. Materials used in this experiment consisted of commercial formulations of (1) a wettable powder containing 15 per cent of parathion, (2) a wettable

powder containing 25 per cent of chlorinated camphene, (3) a wettable powder containing 50 per cent of chlordan, (4) two samples of benzene hexachloride wettable powder containing 6 per cent gamma isomer, and (5) acid lead arsenate. Due to the general confusion existing in 1946 concerning the gamma isomer content of benzene hexachloride, concentrations suggested by the manufacturers were followed for all materials. Treatments were made on June 3, June 9 and June 12. At the time of the first treatment, June 3, about 95 per cent of the shucks had fallen from the fruit. A preliminary check with randomized counts before treatment indicated about 20 per cent injury to the fruit. Sixteen pounds of hydrated lime per 100 gallons were included with the lead arsenate treatments, and 5 pounds of wettable sulfur per 100 gallons were applied for brown rot control with all treatments made on June 3 including the check plots. A list of the treatments and a summary of the results are given in table 2.

Table 2.—Summary of results of 1947 plum curculio experiments.

No.	Material	Lbs. per 100 Gals.	No. of Sprays	Drops Injured	Per Cent of: Injury at Harvest	Total Crop Injured	Total Injury as Drops
1	15% Parathion	1.75	2	85.0	27.0	36.7	29.6
2	15% Parathion	4	2	89.0	29.0	32.7	17.4
3	25% Chlorinated camphene	1	2	95.1	37.8	55.9	61.0
4	25% Chlorinated camphene	2	2	95.0	17.8	38.1	62.3
5	6% Benzene hexachloride (A)	3	3	85.4	23.5	30.4	15.0
6	6% Benzene hexachloride (B)	3	3	84.0	31.3	37.8	12.5
7	6% Benzene hexachloride (A)	3	2	89.7	25.8	32.9	23.4
8	6% Benzene hexachloride (B)	3	2	79.2	29.5	33.7	25.1
9	50% Chlordan	2	2	91.6	31.5	40.1	32.9
10	Lead arsenate	2	2	92.2	18.8	39.6	65.2
11	Lead arsenate	2	1	96.7	27.8	52.4	65.6
12	Untreated check	——	—	95.1	21.8	52.4	68.9
Least significant difference	1%				None	14.5	22.6
	5%				None	10.7	16.7

The summary presented in table 2 after considering all criteria of control, show the organic insecticides parathion, benzene hexachloride, chlordan and chlorinated camphene to be as good or better than lead arsenate for the control of plum curculio. As in the 1946 experiment, most of the drops were found to have been injured by curculio feeding or egg deposition scars. The benzene hexachloride and parathion treatments varied from 79 to 89 per cent injury to the drops in comparison to 92 to 97 per cent injury in the chlorinated camphene, chlordan, both lead arsenate treatments and check plots. The total injury occurring as drops at the 1 per cent level of significance was significantly lower in the parathion, benzene hexachloride and chlordan treatments than in the chlorinated camphene, one and two applications of lead arsenate and the check plots. This reduction of drops in the benzene hezachloride, parathion and chlordan treatments left more fruit on the tree. This is of particular importance if blossom thinning is practised.

Differences in injury to the fruit as measured at harvest time by the different treatments was not statistically significant. However, this might be expected when it is realized that fewer peaches dropped from some of the treatments than from others, and thus produced more mature fruit per tree. Injury to the total crop in the parathion and benzene hexachloride treatments was found to be significantly lower than the injury occurring in the untreated plots, the single application of lead arsenate and the treatment receiving 1 pound of chlorinated camphene at the 1 per cent level of significance. At the 5 per cent level, two applications of lead arsenate, chlordan and the treatment receiving 2 pounds of chlorinated camphene were significantly lower than one application of lead arsenate, 1 pound of chlorinated camphene and

the untreated checks. Differences resulting between two and three applications of benzene hexachloride and two different samples of benzene hexachloride were not statistically significant.

No injury to the peach foliage, buds, fruit, or any part of the tree could be discerned by the benzene hexachloride, parathion, chlorinated camphene or chlordan treatments as used in this experiment. No apparent increase in abundance of brown rot infected fruit in the benzene hexachloride treatments were noted. There was a noticeably lower population of European red mite and two-spotted spider mite on the parathion plots as compared to the other treatments on September 3 and 4.

DISCUSSION.—The treatments used in these experiments as shown in tables 1 and 2, have been evaluated on the basis of injury to the dropped fruit, amount of dropped fruit, total injury to the crop and injury at harvest time since no one method of evaluation alone presents a true picture of the injury to peaches occurring from curculio. As a result of using these methods of evaluation, organic insecticides such as parathion, benzene hexachloride, chlordan and chlorinated camphene are found to be equal to or superior to the use of two applications of lead arsenate for the control of plum curculio. The benzene hexachloride and parathion treatments ran consistently lower than two applications of lead arsenate on total injury to the fruit, but the differences were too small to demonstrate statistical significance. Two applications of 2 pounds of 50 per cent chlordan and two applications of 2 pounds of 25 per cent chlorinated camphene were equal to two applications of lead arsenate in total injury to the fruit. Two applications of lead arsenate applied at the 95 per cent shuck-off stage and 6 days later was superior to a single application made at the 95 per cent shuck-off stage. One application of lead arsenate provided no protection at all.

Both years' results show curculio injury to the dropped fruit to exceed 79 per cent. This seems to indicate that the injury to the fruit by plum curculio is at least a contributing factor to the loss of fruit as drops. Benzene hexachloride treatments resulted in 80 to 90 per cent injury the first year, and 79 to 90 per cent injury the second year. The untreated trees and the lead arsenate sprayed trees varied from 92 to 97 per cent both years. Chlorinated camphene treatments were found to have 95 per cent of the dropped fruit injured, chlordan 92 per cent, and parathion treatments varied from 85 to 89 per cent. In the first experiment 4 applications of benzene hexachloride were found to reduce losses from dropped fruits significantly as compared to lead arsenate. In the second experiment the reduction of losses from dropped fruit is expressed as per cent of total injury occurring as drops. In this experiment, the parathion, benzene hexachloride and chlordan treatments were found to reduce significantly the losses as dropped fruit over 2 applications of lead arsenate at odds of 99 to 1. Observations and the data presented as injury occurring as drops indicate parathion and benzene hexachloride in particular and perhaps chlordan to be not only effective in controlling plum curculio adults, but also to be toxic to the newly hatched larvae or eggs. Chlorinated camphene treated trees were found to produce about the same amount of injury occurring as drops as the trees sprayed with one and two applications of lead arsenate and the check trees. These data indicate that although the injury measured to the total crop with parathion, benzene hexachloride, and chlordan was not significantly superior to lead arsenate, less than one-third of the injury is expressed as dropped fruit in comparison to about two-thirds of the injury occurring as drops with chlorinated camphene, lead arsenate and unsprayed plots. Consequently, the peach grower should have a higher yield of fruit on those trees sprayed with parathion, benzene hexachloride and chlordan than on lead arsenate or chlorinated camphene sprayed trees. Since the injury as measured at harvest did not significantly differentiate between any of the treatments, it may be assumed that the increased yield of fruit is marketable. The reduction of injury occurring as drops is of even more importance, if consideration is given to the increasing use of chemical sprays during bloom to thin peaches. Blossom thinning sprays do not make allowance for the amount of injury to occur from curculio, nor do they permit large numbers of curculio stung fruit to be thinned from the trees by hand. Reduc-

tion of the number of injured drops, though they do not all contain larvae that will mature, should proportionately reduce the curculio population in an orchard the following year.

None of the organic insecticides tested in these experiments were observed to exhibit any deleterious effects to the peach foliage, buds, fruit or wood. Growth on these trees appeared, on the other hand, to be more vigorous and the foliage was more dense and of better color than on the unsprayed trees. This is in comparison to the lead arsenate sprayed trees which had less foliage. poorer color and cankered wood resulting from arsenical injury. Parathion sprayed trees were observed to have considerably lower populations of European red mites and two-spotted spider mites on September 3, 1947 than the other treatment. Benzene hexachloride sprayed trees were observed to have a heavier infection of brown rot in 1946, but this was not noted in 1947. Taste tests of fresh fruits receiving 4 applications of benzene hexachloride in 1946 did not demonstrate any off-flavor.

Under the conditions of the first field trial, applications of benzene hexachloride made at the petal-fall and 35 per cent shuck-off stages were of little value as compared to applications made at the 90 per cent shuck-off stage and a 10 day spray. In the second year's trial with benzene hexachloride, only a slight reduction in injury occurred as a result of using a third application following applications made when 95 per cent of the shucks had fallen and again 6 days later. At least 3 pounds of a wettable powder containing 6 per cent of the gamma isomer should be used in each 100 gallons of spray. Differences occurring between two commercial formulations of benzene hexachloride were negligible.

The differences demonstrated between the use of 1.75 pounds of a 15 per cent parathion wettable powder and 4 pounds, indicate that a dosage lower than 4 pounds is sufficient. A 2-pound concentration containing 25 per cent chlorinated camphene was superior to the same material used at 1 pound. Chlorinated camphene appears worthy of further trial at higher concentrations. Two applications of lead arsenate applied at the 95 per cent shuck-off stage and 6 days later were superior to a single application made at the 95 per cent shuck-off stage. A single application of lead arsenate was little better than no treatment at all.

SUMMARY.—Two years' field experiments show at least 79 per cent of dropped peach fruits to be injured by curculio feeding or egg-laying scars. Benzene hexachloride, and parathion, were found to be superior to lead arsenate by reducing the loss of fruits as drops and by the reduction of total injury to the fruit crop. Chlordan was superior to two applications of lead arsenate in reduction of losses as drops and was as good as lead arsenate in reducing the total injury to the crop. Chlorinated camphene caused as much loss of dropped fruits as lead arsenate. Two applications of 2 pounds of 25 per cent chlorinated camphene were equally effective in reducing total injury to the fruit as to two applications of lead arsenate and was significantly superior to two applications of 1 pound of chlorinated camphene. Chlorinated camphene should be tested further at higher concentrations. Two applications of lead arsenate were superior to one application, which was of little or no value Benzene hexachloride, parathion and possibly chlordan appear to be toxic to newly hatched larvae or eggs in addition to their toxicity to adults. No injury to the foliage, fruits, buds or tree was observed with any of the organic insecticides used. Benzene hexachloride as used in these tests did not flavor the fruit at harvest.

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DDT and Benzene Hexachloride in Sprays to Control Peach Tree Borer[1,2]

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Of the insects causing injury to peach in New York, the peach tree borer, *Sanninoidea exitiosa* (Say), has been one of the more difficult for which to find a satisfactory control. Methods utilizing paradichlorobenzene and emulsions of ethylene or propylene dichloride occasionally have resulted in serious injury to trees. Furthermore, any borers at points 6 inches or higher on the trunks escape the treatment. Often, control treatments are deferred until late fall or even the following spring after the current generation of larvae have had several months in which to inflict damage. This situation and the early report by Driggers & Smith (1944) indicating reductions in borer populations in trees sprayed with DDT to control oriental fruit moth stimulated interest in this spraying method. This article is a report of results obtained in experiments with DDT sprays under New York conditions during the past three seasons. Also included is a limited amount of data on the effectiveness of benzene hexachloride used to eradicate established borers.

Laboratory Tests.—Three series of preliminary tests were carried out in August 1945. Freshly cut, 7-inch lengths of peach limbs about 1.5 inches in diameter were placed upright in moist sand in clay pots. About 3 inches of limb remained exposed and the upper end was beveled to eliminate rough edges or crevices which might facilitate entrance by borers or make a spray coverage less uniform. The pots were placed on a turntable and the materials applied with a paint sprayer. Once the spray had dried thoroughly the pots were set in shallow water and empty clay pots inverted over the upper ends of the limbs to prevent excessive loss of moisture. The spray coverage was complete except for a half-inch circle on the exposed end which was covered during the treatment. The 20 recently-hatched, larval borers transferred to each limb in each test were placed in this unsprayed area.

In the first 2 series DDT was used at rates of one pound or higher per 100 gallons. The kill of larvae was complete on all treated limbs. On unsprayed limbs, infested and maintained under identical conditions, a maximum of seven and, for the six limbs, an average of four borers became well established.

The third test included concentrations down to 2 ounces of toxicant per 100 gallons as well as two distinct formulations. Three days after spraying, 10 recently-hatched, borer larvae were placed on each limb. On the fourth day each limb received a second group of 10 larvae. At the end of 2 weeks the limb sections were removed from the sand and counts made of living, well established borers. The results (Table 1) indicated that 1 pound of technical DDT, formulated as a wettable powder, might provide satisfactory borer control. The apparently greater effectiveness of the DDT in kerosene emulsion needs further investigation on the influence the oil itself might have under these conditions.

Field Experiments, 1945.—This experiment was to establish the effectiveness of several concentratilons of DDT under field conditions and the value of one, two and three applications of this material in the form of sprays directed onto the trunk and lower limbs. This report includes only the results obtained with the 1-pound dosages.

The test was conducted in a 6-acre block of 7-year-old Elbertas. On these trees the bark was essentially smooth and the trunks relatively free from scars or wounds. The usual spring and early-summer discing operations had piled a 6 to 10-inch ridge of soil around each trunk. About a week following the first spray treatments the grower removed this soil with hand implements. This operation not only exposed some unsprayed surface but also destroyed many full-grown borers in cocoons.

Treatments were made with a conven-

Eastern Branch Program.

[1] Journal Paper No. 737, New York State Agricultural Experiment Station, Geneva, N. Y. December 12, 1947.

[2] The authors wish to express their appreciation to Dr. J. A. Adams, Poughkeepsie, N. Y., who cooperated in experiments in the Hudson River Valley area.

tional orchard sprayer supplying about 400 pounds' pressure to the single-nozzle spray gun. In making these treatments the operator circled each tree while directing a fog-like spray onto the scaffold limbs and crotch and a forceful, more direct stream against all sides of the trunk. About 5 quarts of liquid were used for each tree. With the exception of sulfur dusts, no other chemicals were applied to these trees during the course of the experiment.

In each row of 15 trees comprising a treatment, 5 trees received only the first application, 5 received both first and second and 5 were treated three times. A center row of 15 trees and an 11-tree row adjacent to the experimental block were left untreated. Applications were made on July 11, August 2 and August 23. In June, empty pupal cases of borers, probably the lesser peach tree borer *Synanthedon pictipes* (G. & R.), had been found protruding from scarred areas on the upper trunk and limbs and on July 6 several pupae of the peach tree borer were collected. On August 2 the number of empty pupal skins and cocoons averaged slightly more than one per tree. The times of treatment corresponded closely with the periods when DDT sprays were applied in nearby orchards for oriental fruit moth control. Borer counts made in May of the following year are summarized in table 2.

Although some reduction of borer populations appears to have resulted from the use of DDT in these sprays, the data presented in table 2 do not show clearly the benefits realized from these treatments. Notes, taken when counts were made, reveal that, of the three borers listed for 3 applications on row 15, one was at the upper end of a large scar and the remaining two in a limb wound about 3 feet from the trunk. In the same row, where 2 treatments were made, 4 of the 5 borers were found on one tree in a large, protected scar under the base of a branch. In contrast, where but one application was used, only two of the six larvae were associated with scars or other areas offering protection to the young borers.

Table 1.—Results obtained in the laboratory when recently-hatched peach tree borer larvae were placed upon peach limbs sprayed with DDT.

Toxicant per 100 Gallons	Number of Living Borers in Bark[1]
Wettable powder with 40 per cent DDT	
0.25 lb.	4
0.5 lb.	5
1.0 lb.	0
Emulsion of kerosene with 5 per cent DDT	
0.125 lb.	1
0.25 lb.	1
0.5 lb.	0
1.0 lb.	0
No treatment	
A	18
B	14

[1] Equals borers surviving from total of 40 used on two replicates.

Table 2.—Results obtained with two formulations of DDT[1] sprayed on peach trees in one, two and three applications to control peach tree borer.

Number and Dates of Applications	Number of Borers in 5 Trees			
	DDT-A[2] Row 15	Untreated Row 17	DDT-B[3] Row 20	Untreated Row 21
1. July 11	6	19	17	23[4]
2. July 11, Aug. 2	5	21	11	19
3. July 11, Aug. 2 & 23	3	17	3	24

[1] One pound toxicant per 100 gallons.
[2] *Deenate 25-W* furnished by duPonts.
[3] *Gesarol AK-40* furnished by Geigy Company.
[4] But one tree available; total estimated from other checks.

The apparent superiority of DDT-A loses significance when the data assembled for the DDT-B formulation are examined more critically. For example, two of the three larvae found on trees receiving 3 applications were in a split-crotch wound. Where two treatments were made, 7 of the 11 borers were in injured areas at the base of one tree. More scars or wounds were listed for the one-treatment trees in row 20 than for corresponding trees in row 15. In other words, the degree of control obtained was indicative of the condition of the surface of the tree trunk, crotch and limbs rather than the type of DDT formulation used.

Grower Field Tests, 1946.—Two growers in the Hudson River Valley cooperated in continuing peach tree borer tests in 1946. Orchard A was a 3-acre block of 5 to 7-year-old Golden Jubilees growing in heavy clay soil. A preliminary examination indicated a high borer population and serious damage from borer activity in previous years. With the exception of 8 trees in one corner the entire orchard received 4 sprays of DDT during

the season. On July 10 and August 2 the material was applied to entire trees to control fruit moth as well as the borer. To assure complete coverage of trunks and scaffold limbs one operator rode a stoneboat pulled behind the sprayer while a second sprayed from the tank. The postharvest applications, on August 21 and September 4, were directed against the trunks, crotches and scaffold limbs only. A 50 per cent wettable powder was employed throughout the test at a rate providing 1.5 pounds of actual toxicant per 100 gallons.

Orchard B was a 2-acre block of 6-year-old Elbertas growing in sod. An adjoining, similar block served as a check. Trees in both these orchards were infested badly and many seriously injured by peach tree borer. Orchard B was sprayed but twice, about July 6 and again 3 weeks later. The treatments were confined to trunks and limb bases, no attempt being made to cover foliage or fruit. DDT was used in the same form and concentration as in orchard A.

Table 3.—Control of the peach tree borer in 1946 with DDT[1] in 2 grower-sprayed New York orchards.

Orchard	Number of Applications	Number of Borers in in 10 Trees[2,3]	
		Unsprayed	Sprayed
A	4	95	7
B	2	65	11

[1] One and one-half pounds actual DDT per 100 gallons.
[2] Based upon counts from 8 check and 20 treated trees from A and 10 check and 12 sprayed trees in B.
[3] Includes some larvae from 1945 hatch—partly grown when treatments were made.

Counts were made in both orchards during the early spring of 1947. In orchard A, count trees were examined again in early July and a number of borers found that obviously were missed on the earlier date. A summary of the data obtained in these two orchards is presented in table 3.

FIELD EXPERIMENTS, 1947.—The purpose of this experiment was to verify, on a larger scale and under more difficult conditions, some of the earlier findings and to compare wettable powders and emulsions containing DDT. As the experiment progressed, an opportunity was provided to determine the effectiveness of benzene hexachloride applied as an eradicant after the current season's hatch of peach tree borers had been nearly completed.

In western New York, an Elberta orchard with trees ranging in age from 5 to 20 years and growing in a sandy loam soil was selected for the test. It contained 33 east-west rows of 10 trees each. A second block of 7-year-old Elbertas adjoined the experimental block on the east. During the course of the experiment the center east-west row (row 17) and the adjacent block remained untreated with insecticides except for 2 sprays and 3 dusts of DDT-sulfur directed primarily at foliage and fruit to control oriental fruit moth. The outside rows at the north and south ends received oriental fruit moth treatments plus two treatments with plain water applied to trunks and limbs. These water applications were made in the same manner and at the same times as the regular DDT sprays for peach tree borer control. It became apparent, when counts were made, that spraying with plain water had had no effect upon the peach tree borer population. Therefore, the counts made on 6 trees from this treatment, 5 from row 17 and 5 from rows adjacent to the experimental block, or a total of 16 trees, became the basis for all data in the untreated category. Almost all treated trees included among those counted were 8 years of age or older.

The DDT and plain water sprays were applied with a single-nozzle spray gun operated from a low platform at the rear of a conventional orchard sprayer delivering 600 pounds pressure. In this way the liquid was used at about one and one half gallons per tree. In making benzene hexachloride applications the operator circled each trunk and employed slightly more than 2 gallons per tree. In all this spraying, streams were directed against all sides of the trunks, crotches and scaffold limbs.

Moths of the lesser peach tree borer were observed flying in nearby orchards on June 10 but careful checks indicated the first peach tree borer emergence in the period July 20 to 25—the first moth being seen on July 25. The first applications of DDT were made on July 31 and the later ones on August 19. The single benzene hexachloride eradication-treatments were applied on August 26.

On July 19 and 25 counts of the entire borer population on 25 trees scattered throughout the orchard indicated an aver-

age of about 8 per tree with a maximum of 40 per tree. These and all subsequent examinations included the upper trunk, crotch and scaffold limbs to points 2 feet from the trunk as well as the tree base. At that time, the population consisted of empty pupal skins, pupae and larvae in cocoons, and immature larvae ranging from those nearly full-grown to some very small ones. These latter, being almost exclusively in wounds on trunks and limbs, presulably represented the new generation of lesser borer.

growth—quite evident in older trees—were not classed as scars or wounds. In determining populations in this experiment the numbers of larvae found in wounds were kept distinct from the figures representing those that had entered directly into uninjured, normal bark. The wounds themselves varied greatly in number and size from tree to tree and between groups of treated trees. To make the results directly comparable, therefore, the wounds from which borer counts were made were classified into size groupings

Table 4.—Results obtained in 1947 with DDT and BHC in sprays directed against the trunks and limbs of peach trees to control peach tree boreer.

Materials and Amount of Toxicant per 100 Gallons	Number of Borers in 10 Trees			
	Entirely in Wounds[1]	Direct Entries		Total Number
		Ground Level[6]	Trunk & Limbs	
DDT sprays on July 31 and August 19				
Wettable powder,[2] 1.5 lbs.	72	1 (1)	0	73
Emulsion,[3] 1 lb.	82	4 (1)	0	86
Untreated	93	46 (4)	50	189
Benzene hexachloride spray on August 26 only				
Wettable powder,[4] 0.24[5] lb.	45	2 (1)	6	53
Wettable powder,[4] 0.48[5] lb.	43	2	4	49

[1] Adjusted to compensate for variations in number and size of wounds; includes lesser peach tree tree borer population.
[2] *Persisto*, furnished by California Spray Chemical Company.
[3] Furnished by Grange-League-Federation, Inc.
[4] Furnished by Niagara Spray Chemical Company.
[5] Gamma isomer.
[6] Figures in parenthesis indicate number of borers from 1946 hatch included in counts; includes everything below a point 6 inches above the actual soil surface.

Repeated observations on trees in neighboring orchards indicated that peach tree borer emergence in that area was completed for the season by the end of August. Also, it became evident that some larvae, hatched in 1946, would fail to pupate in 1947 and remain in the trees as larvae until 1948. These borers were well established and probably half grown when the first DDT sprays were applied.

Data from this experiment were collected during October and are set forth in table 4.

Earlier studies had shown the influence upon borer populations of the presence of scars or wounds in the bark. As used in this report, wounds are defined as any break in the bark surface caused by winter injury, pruning, rubbing or cultivating implements and splits in weak crotches. Roughness or cracking in the bark brought about by normal trunk and reduced to a common numerical basis for the series of treatments and check.

In table 4, borers listed as having entered directly into the bark were separated on the basis of their location above or below a point 6 inches above the soil surface. Or, to emphasize an important advantage of the spraying method, a distinction has been made between those susceptible to control by methods utilizing paradichlorobenzene or dichlorides and those that normally would escape such treatments.

The data shown in table 4 support previous findings with respect to the effectiveness of DDT in sprays at dosages of 1 or more pounds of toxicant per 100 gallons. As applied in this test, DDT sprays are relatively ineffective against borers associated with wounds. The high populations recovered from trees omitted from the borer control program but which

received DDT-sulfur in 2 sprays and 3 dusts for fruit moth control are evidence that peach tree borer control results from DDT sprays directed primarily onto the trunk and limb bases.

The results obtained from the use of benzene hexachloride indicate certain advantages over DDT. In this test one spraying with benzene hexachloride after the borer eggs were hatched and the young larvae established, reduced the total borer population about 70 per cent. A study of the figures in table 4 shows both dosages to be nearly as effective as DDT in reducing the number of borers having direct entries; apparently it is more effective than DDT in freeing the wounds of borers. These conclusions are supported by observations made a week after the spray treatments. At that time dead as well as living larvae of all ages could be found in wounds and in burrows from direct entries on the benzene hexachloride-treated trees; dead larvae were not found in similar situations on the check and DDT-treated trees.

SUMMARY.—Sprays containing DDT were employed in preliminary laboratory tests and, during 3 seasons, under field conditions to control the peach tree borer. Benzene hexachloride was employed in 1947 to eradicate established borers after egg hatching was complete.

Results show that, under New York conditions, DDT, at concentrations of one or more pounds of toxicant per 100 gallons, sprayed directly onto trunks, crotches and limb bases is effective against the peach tree borer. According to these results applications should begin with the first hatch and be repeated at 3-week intervals until the latter part of August. Lesser peach tree borer and regular peach tree borer larvae associated with wounds are not checked noticeably by these treatments.

Near the end of the hatching period, one application of benzene hexachloride providing 4 ounces of gamma isomer per 100 gallons was nearly as effective as two sprays of DDT in checking borers in direct entries on uninjured bark; it was more effective than the DDT in reducing the borer populations in wounds.

Both materials used as sprays have marked advantages over methods using paradichlorobenzene or dichlorides.

LITERATURE CITED

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Summer Control of Pear Psylla During 1947[1]

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Injury due to the pear psylla, *Psylla pyricola* Foerst., has been extremely severe throughout eastern New York for the last two seasons. In seasons when climatic conditions are favorable for the development of this insect, the dormant spray programs now in general use can not be depended upon to effect a sufficient degree of control to prevent an outbreak later. In such seasons summer control programs must supplement those designed for the dormant season. In the summer of 1947 three field tests, similar to those previously reported (Hamilton 1947), were carried out in orchards having high populations of pear psylla. The insecticides tested were nicotine sulfate, parathion, chlorinated camphene, cube root, hexaethyl tetraphosphate and tetraethyl pyrophosphate, piperonyl cyclonene and piperonyl butoxide with pyrethrum, chlordan, and pyrethrum.

The first test was made on May 27, the second on July 29, and the third on September 3. The sprays were applied by means of a 35-gallon-per-minute hydraulic sprayer equipped with a single-nozzle gun containing a disk with a 0.56-inch orifice. In the May and September tests each treatment was applied to a small, unreplicated block of trees, and in the July tests each treatment was applied to a single tree in duplicate blocks of trees.

Eastern Branch Program.

[1] The work reported herein was conducted in cooperation with the New York State Agricultural Experiment Station at Poughkeepsie, N. Y.

From 10 to 15 spurs were selected at random on each of 2 trees per treatment, and the degree of control was determined by comparing the number of nymphs per spur in the sprayed plots with the number in the unsprayed plots. The effect of the treatments on adults was determined by counting, 30 minutes after spraying, the dead adults on 2 cloth trays that were placed under the trees just prior to the spraying. Records obtained by this method did not always indicate the full value of a treatment against the adults, but served the purpose. With some treatments dead adults stuck to the foliage instead of dropping to the ground or into the trays, and in others slow-acting materials might have shown to better advantage if the trays had been left in place for a longer period.

The results of the various tests, as given in tables 1 to 3, are discussed in the following paragraphs.

NICOTINE SULFATE.—In his previous paper the writer suggested that the variation in results obtained with nicotine sulfate sprays applied to control pear psylla nymphs was probably due to differences in the air and water temperatures at the time of application. The results obtained under field conditions in 1947 support this suggestion. For example, nicotine sprays applied on July 29 (table 2), when the air temperature was 84° F., were more effective than those applied on May 27 (Table 1), when the air temperature was only 68° F., even though the initial population was about the same. The temperature of the spray water was not determined, but was undoubtedly lower on May 27 than on July 29.

In most of the plots sprayed with nicotine sulfate in 1947, it was used at the low concentration of 8 ounces to 100 gallons, so that the supplementary materials would have a chance to show their value.

The control obtained with nicotine sulfate was not entirely satisfactory. Because the material had little or no value as a residue, the nymphs that survived the initial treatment were able to rebuild infestations rapidly. The three plots in which results were taken 9 days after the July 29 spraying had heavy enough infestations at that time to cause heavy deposits of honeydew and consequent smutting of the fruit.

The 16-ounce strength of nicotine sulfate was definitely superior to the 8-ounce strength when supplementary materials were not included. It is believed that the DDT used with the higher concentration in May did not affect the results materially. The combination of summer oil and nicotine sulfate was more effective against nymphs than the nicotine alone, and the combination of 10 pounds of lime with the nicotine was even more effective. Both these formulations increased the knockdown of adults as well as the kill of nymphs. However, there are objections to the use of either combination. The formulation containing oil may result in severe injury to fruit and foliage if it is used shortly before or after DDT is applied for codling moth control, whereas the lime-nicotine mixture leaves heavy visible deposits on the fruit and may cause russeting if applied when temperatures are extremely high. The lime also increases the volatility of the nicotine to such an extent that spray operators may become ill when applying it over long periods.

A formulation in which 1 pound of lime and 2 ounces of a wetting agent,[1] were used with nicotine sulfate proved to be about as effective against nymphs as the formulations containing summer oil or a higher concentration of lime, and knocked down more adults. It also appeared less likely to russet fruit than the formulation

Table 1.—Tests with summer sprays applied to Clapp Favorite pear trees on May 27 for control of pear psylla nymphs, 1947.

MATERIALS (QUANTITIES PER 100 GALLONS)	AVERAGE NUMBER OF NYMPHS PER SPUR AFTER 2 DAYS
Nicotine sulfate (40%) 8 oz. plus:	
No accessory material	9.6
Summer oil 1 gal.+blood albumin 8 oz.	6.5
Hydrated lime 10 lb.	2.1
Nicotine sulfate (40%) 1 lb.+DDT (50%) 2 lb.	7.4
Parathion	0.0
Chlorinated camphene:	
25% Wettable powder 2 lb.	11.3
50% Emulsifiable solution 2 lb.	10.4
Cube root+summer oil 1 gal.:	
Powder (4.8% rotenone) 2 lb.	2.8
Commercial paste (50% cube) 1 lb.	5.7
Hexaethyl tetraphosphate:	
Technical 8 oz.+spreader 2 oz.	1.2
Commercial mixture (50%) 16 oz.	1.1
Tetraethyl pyrophosphate:	
Technical 4 oz.+spreader 2 oz.	0.0
Piperonyl cyclonene (8%)+pyrethrins (0.8%):	
16 oz.	1.8
32 oz.	1.8
Chlordan, emulsifiable solution (50%) 16 oz.	14.3
Pyrethrum flowers 2 lb.+summer oil 1 gal.	3.9
Untreated	28.2

A formulation in which 1 pound of lime and 2 ounces of a wetting agent,[1] were used with nicotine sulfate proved to be about as effective against nymphs as the formulations containing summer oil or a higher concentration of lime, and knocked down more adults. It also appeared less likely to russet fruit than the formulation

[1] *Triton B-1956*, a phthalic glyceryl alkyd resin.

Table 2.—Tests with summer sprays applied to pear trees on July 29 for control of the pear psylla, 1947.

Materials (Quantities per 100 Gallons)	Average Number of Nymphs per Spur After				Adult Knock-Down (Number per Square Foot)
	2 Days	9 Days	27 Days	41 Days	
Bartlett					
Nicotine sulfate (40%) 8 oz. plus:					
No accessory material	4.8	—	—	—	34
Summer oil 1 gal.+blood albumin 8 oz.	1.6	10.4	32.6	—	52
Hydrated lime 10 lb.	0.3	31.9	28.4	—	62
Hydrated lime 1 lb.+spreader 2 oz.	0.7	14.8	43.4	—	101
Nicotine sulfate (40%) 1 lb.	1.2	—	—	—	9
Untreated	26.1	—	—	—	—
Clapp Favorite					
Parathion (15%) 1 lb.	0.0	0.0	3.8	37.9	6
Chlorinated camphene (25% wettable powder) 4 lb.	0.3	1.9	11.2	24.1	2
Cube root (4.8% rotenone) 2 lb.+summer oil 1 gal.	0.0	0.2	4.8	4.5	43
Hexaethyl tetraphosphate:					
Technical 8 oz.+spreader 2 oz.	0.5	6.6	20.4	—	33
Commercial mixture (50%) 16 oz.	0.3	25.9	—	—	62
Tetraethyl pyrophosphate:					
Technical 4 oz.+spreader 2 oz.	0.05	22.0	—	—	53
Piperonyl cyclonene (8%)+pyrethrins (0.8%) 16 oz.	0.7	34.0	—	—	34
Piperonyl cyclonene (40%)+pyrethrins (4%) 8 oz.	0.05	12.0	—	—	57
Piperonyl butoxide (8%)+pyrethrins (0.8%) 16 oz.	2.8	14.4	—	—	62
Piperonyl butoxide (40%)+pyrethrins (4%) 8 oz.	0.2	18.9	—	—	51
Untreated	6.4	14.8	36.5	11.6	

containing more lime, left only a light visible residue on the fruit, and would not interfere with the use of DDT, as would summer oil.

PARATHION.—A wettable powder containing 15 per cent of parathion, used at the rate of 1 pound to 100 gallons of spray, killed 100 per cent of the nymphs present in all three tests. No injury to the fruit or foliage occurred even though weather conditions varied widely. In addition, no nymphs were present 9 to 12 days after application and few were present after 23 or 27 days. This was in marked contrast to the situation when nicotine sulfate was used. Heavy populations of nymphs were found in the thiophosphate plot 41 days after spraying, but this might not have occurred if a large block, or the entire orchard, had been treated.

Table 3.—Tests with summer sprays applied to Kieffer pear trees on September 3 for control of pear psylla nymphs, 1947.

Concentration (Pounds per 100 Gallons)	Average Number of Nymphs per Spur After		
	2 Days	12 Days	23 Days
Parathion (15 per cent)			
0.5	0.0	0.2	0.2
1	0.0	0.0	0.1
2	0.0	0.0	0.0
Chlorinated camphene (25 per cent)			
2	3.0	0.0	0.5
3	1.4	0.0	0.0
4	0.3	0.0	0.0
Untreated	29.2	32.8	12.4

In tests with several concentrations of parathion applied early in September, as little as 8 ounces per 100 gallons appeared to be effective. All nymphs present at the time of application were killed, and practically none were present 23 days later. Knock-down of adults at the time of spraying was comparatively small. No attempt was made to determine the effect of this material on adults over a longer period. Since it has given good results for codling moth control when used on apples at the rate of 2 to 3 pounds per 100 gallons, it has great promise for the control of both pear psylla and codling moth on pears.

Determinations of parathion residues from samples of leaves and fruit collected soon after application, and 7, 14, and 28 days later, showed that on both the fruit and foliage they weathered rapidly, re-

gardless of the concentration used (Table 4). Residues remaining after 14 days were very light. Incidentally, no ill effects were noticed by any of the staff which could be attributed to the use of sprays containing this material. However, only small plots were treated, and no information is available as to the reaction of workers exposed to this material for long periods of time.

CHLORINATED CAMPHENE.—A preliminary test of chlorinated camphene used as a 25 per cent wettable powder and as a 50 per cent emulsifiable solution was made on May 27, and the results were not especially promising. Nymph counts made 2 days after the application showed that the population was greater than where nicotine sulfate sprays were used. In July and September additional tests of the 25 per cent wettable powder were made at increased concentrations, with better results. The 4-pound strength reduced the nymph population to a low level, and the July application held it there for at least 9 days and the September application for 23 days. In September 2 and 3 pounds of the 25 per cent wettable powder per 100 gallons also gave effective control of the pear psylla, and the nymph population on the treated trees remained at a low level for at least 23 days.

The results of all these tests indicate that chlorinated camphene may be superior to nicotine sulfate for pear psylla control. No injury to the fruit or foliage of trees sprayed with this material was apparent. Immediate kill of adults was low.

CUBE ROOT.—Two cube products were tested, a ground cube root containing 4.8 per cent of rotenone and a commercial paste containing 50 per cent of cube root. The results were similar to those reported in 1946. Two pounds of the ground cube root used with 1 gallon of summer oil to make 100 gallons of spray reduced nymph populations to a low level within 48 hours and maintained its effectiveness for at least 3 weeks. The paste, which was used only in the May tests, gave a high degree of control when used with summer oil. The paste, however, is much more difficult to mix than a powder or liquid. Knock-down of adults was high, owing largely to the oil present. No spray injury was observed.

HEXAETHYL TETRAPHOSPHATE AND TETRAETHYL PYROPHOSPHATE.—A technical grade of hexaethyl tetraphosphate and a commercial preparation containing 50 per cent of this material were tested during May and July. A wetting agent[1] was used with the technical material. In all the tests hexaethyl tetraphosphate was used at 8 ounces per 100 gallons of spray. Immediate kill of nymphs present at the time of application was high in all instances. However, nymphs from eggs present at this time were not affected, and the spurs were rapidly reinfested. Adult knock-down was about the same as with nicotine sulfate. Injury in the form of a burned ring occurred on an occasional fruit at the point where the sprays ran off, and in May the 50 per cent mixture caused red lesions on new growth.

A spray containing 4 ounces of tetraethyl pyrophosphate with 2 ounces of the spreader per 100 gallons killed most of

[1] *Triton B-1956.*

Table 4.—Parathion residues on fruit and foliage of Kieffer pear trees sprayed on September 3, 1947.[1]

CONCENTRATION (POUNDS PER 100 GALLONS)	RESIDUE (P.P.M.) AFTER							
	4 Hours		7 Days		14 Days		28 Days	
	Fruit	Foliage	Fruit	Foliage	Fruit	Foliage	Fruit	Foliage
0.5	0.8	24.1	0.2	1.6	0.1	0.6	—	—
1	1.5	29.8	0.4	2.3	0.2	0.9	—	—
2	2.5	77.5	0.6	5.9	0.4	1.6	0.3	1.7
Untreated	<0.1	0.8	<0.1	0.0	<0.1	<0.1	<0.1	<0.1
Total rainfall between the time the sprays were applied and the time the samples were collected (inches)	0.00		0.37		1.20		1.94	

[1] Determinations by P. R. Averell, American Cyanamid Company.

the nymphs present at the time of application. Although the immediate kill was better than with hexaethyl tetraphosphate, nymphs soon reappeared in numbers as when the latter material was used. In all the tests severe ringing of the fruit occurred at the point of run-off, and in May two different products containing this same compound caused many of the lenticels on new growth to become swollen and red.

PIPERONYL COMPOUNDS WITH PYRETHRINS.—Tests were made with four commercial products containing pyrethrins and a piperonyl compound. Two of the products contained 0.8 per cent of pyrethrins and 8 per cent of either piperonyl cyclonene or piperonyl butoxide. The other products contained 4 per cent of pyrethrins and 40 per cent of one of the piperonyl compounds.

Piperonyl cyclonene with pyrethrins gave high kills of nymphs present at the time of application and knocked down many adults, as previously reported by the writer. Piperonyl butoxide with pyrethrins was about equally effective. Nymph populations built back rapidly, however, in all plots, and both materials caused some injury this season. Piperonyl cyclonene with pyrethrins caused the lenticels of the leaves to become red when it was applied to new growth and injured the fruit at the point of run-off when applied to the variety Clapp Favorite in July. Injury to fruit was greater from the spray containing 8 per cent of piperanyl cyclonene than from that containing 40 per cent. Piperonyl butoxide with pyrethrins caused greater injury to fruit at the point of run-off than did piperonyl cyclonene. The solvent used in preparing the formulations may have been more or less responsible for the injury they caused this season. The piperonyl cyclonene tested in 1946 caused no injury. However, it was not used on tender foliage in 1946, as it was this season.

CHLORDAN.—A commercial emulsion containing 50 per cent of technical chlordan was tested once in the May series of tests. The results were so poor—only about a 50 per cent reduction in the nymph population—that the material was not tested again during 1947. Chlordan caused no plant injury in this test. Additional tests with other formulations and higher concentrations of chlordan are, of course, needed to establish its value for control of the pear psylla.

PYRETHRUM.—Like chlordan, pyrethrum was used in but a single test in 1947. In May, 2 pounds of pyrethrum flowers in combination with 1 gallon of summer oil in 100 gallons of spray reduced the nymph population 86 per cent without injuring the foliage. This reduction compared favorably with that effected by nicotine sulfate and justifies further tests of this material.

SUMMARY.—Nicotine sulfate, alone and with other materials, parathion chlorinated camphene, cube root and oil, hexaethyl tetraphosphate, tetraethyl pyrophosphate, piperonyl cyclonene with pyrethrins, piperonyl butoxide with pyrethrins, chlordan, and pyrethrum with oil were evaluated in field tests for control of the pear psylla during the summer of 1947.

Nicotine sulfate sprays killed a high percentage of the psylla nymphs present at the time of application, but populations built back rapidly where they were used. Kills were higher at high temperatures, and when lime or oil were included in the formulation.

Sprays containing hexaethyl tetraphosphate, tetraethyl pyrophosphate, piperonyl cyclonene with pyrethrins, and piperonyl butoxide with pyrethrins gave results similar to those obtained with nicotine sulfate sprays and, in addition, sometimes injured tender foliage and the fruit at the point of run-off.

Parathion was remarkably effective against the nymphs present at the time of application and, in addition, held the psylla population to a low level for an extended period. It caused no plant injury, and its residues on fruit weathered to 0.4 p.p.m. or less in about 2 weeks. Chlorinated camphene and cube root with oil also showed promise from the standpoint of both immediate kill and residual effectiveness and caused no injury.

Chlordan was comparatively ineffective in a single test, but pyrethrum flowers showed promise.

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Fogging with DDT for Japanese Beetle Control

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Mosquitoes, flies and Japanese beetles present a serious control problem in many Maryland communities. Proper spraying with DDT has been found to give relief from all three of these pests. The conventional method of spraying, while effective is quite expensive, especially in labor and time. During the war, fog applicators were developed that proved effective for giving relief from mosquito and fly infestations. These machines are fast and economical of time and labor. In the city of Cambridge it took three men 30 days to spray the city once with conventional equipment whereas two men thoroughly fogged the city in 3 days.

During the past summer a fog applicator was used experimentally in fogging eight Maryland cities and towns to determine the efficiency of DDT as an aerosol fog for relief from mosquitoes, flies and Japanese beetles. Fogging with a 5 per cent solution of DDT, in No. 2 fuel oil, applied as a medium to coarse fog particle sizes 40 to 60 microns, give relief from flies and mosquitoes, but failed materially to reduce Japanese beetle populations. A limited number of beetles were killed, but not enough for the operation to be considered efficient or satisfactory for their control.

Experimentation gave evidence that greatly improved results could be obtained through certain adjustments. These adjustments involve consideration and coordination of meterological conditions, size of the fog particles and the amount of DDT contained in the formulation used. With these factors in proper adjustments, fogs may be used to good advantage in many situations for Japanese beetle control.

This paper is based on data obtained by fogging, under regulated conditions, caged Japanese beetles, a miscellaneous assortment of infested home orchards, roadsides, corn fields and eight cities or towns. Most of the cities and towns were fogged from 2 to 4 times. It is presented to point out some requirements that appear essential for the effective use of DDT fogs in Japanese beetle control activities.

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METEOROLOGICAL CONDITIONS.—Adverse wind movements and air currents may materially affect the efficiency of aerosol fogs. Fogging should not be attempted in strong winds or when air currents are moving upward rapidly. Best results are obtained under conditions of calm with other meteorological factors that tend to enable the fog to engulf the area under treatment, hang close to the ground and hold without rapid dissipation. These conditions, in Maryland, seem to occur most frequently in late evening or early morning. The speed with which a fog is drifting or dispersing has a definite influence on its efficiency for killing Japanese beetles. Fast drifting fogs, as those encountered with stiff breezes, are relatively inefficient.

FOG PARTICLE SIZE.—In work with mist blowers, Potts (1946) has shown that droplet or spray particle size will influence the deposit of insecticides. It is well known that many of the particles in a smoke aerosol are so small that their insecticidal value is negligible. Foggers understand that as they increase the particle size of the fog, insecticidal efficiency is increased. Results in this respect are obvious when fogging for Japanese beetle control. Fine or dry fogs are relatively inefficient as compared with coarse or wet fogs. With a formulation containing 5 per cent DDT with the applicator adjusted to deliver a fog with particles ranging from 40 to 60 microns, 100 per cent of all beetles, exposed in cages, at 50 ft. from the machine were killed. When adjusted to deliver a fog with particles 10 to 20 microns, only 40 per cent were killed.

QUANTITY OF DDT IN FORMULATION.—In fogging for Japanese beetle control a rich insecticide mixture should be dispersed. With conventional sprayers the writers have found that as the amount of DDT is increased the efficiency of the results as they pertain to the quickness of kill and lasting qualities is increased. A similar relation was observed to occur when DDT was applied as a fog. As the formula was enriched the efficiency of the kill was increased. When a 5 per cent DDT solution with particle size 40 to 60 microns was dispersed in town fogging, with

the machine traveling at 4 miles per hour very few beetles would fall to the ground and die. When the formulation was enriched to contain 15 per cent DDT the streets would be covered with fallen beetles. Data on the relative efficiency of fogging with formulations containing different amounts of DDT were gained through regulated tests in which beetles were caged and fogged. Table 1 shows that, as the formulation was enriched the speed with which a fog is drifting or dispersing itself has a definite influence on the area over which the fog will kill Japanese beetles.

Data collected on caged beetles, under conditions of relative calm in which wind velocity varied from 1 to 2 miles per hour, showed that the killing range of the horizontal swath of a fog varied with the amount of DDT in the insecticidal formulation. With formulations containing 20

Table 1.—Results obtained from fogging for control of Japanese beetles under conditions of calm. Machine adjusted to deliver fog particles of from 40 to 60 microns. Observations made on caged beetles. Formulations prepared with No. 2 fuel oil and sufficient solvent to put the DDT in solution.

DDT Content of Formulation	Length of Period After Treatment	Percentage of Beetles Down or Dead			
		Distance of Beetles from Applicator			
		10 ft.	30 ft.	60 ft.	100 ft.
7.5%	1 hr.	61.7	61.5	47.0	36.5
	5 hrs.	91.6	93.5	73.0	29.0
	24 hrs.	97.0	100.0	92.7	57.5
10%	1 hr.	80.5	62.5	47.2	23.2
	5 hrs.	97.6	90.6	87.6	55.0
	24 hrs.	99.7	99.2	96.7	92.5
15%	1 hr.	90.0	78.5	45.7	34.7
	5 hrs.	99.6	98.6	95.3	80.5
	24 hrs.	100.0	100.0	99.0	97.5
20%	1 hrs.	91.5	92.5	78.5	54.4
	5 hrs.	99.0	95.0	96.5	98.5
	24 hrs.	100.0	100.0	100.0	100.0

fog became more efficient from the standpoint of quickness of knockdown and that of total kill at varying distances from the applicator.

With a formulation containing 7.5 per cent DDT at a distance of 100 feet from the machine, 36.5 per cent of the beetles were down at the end of 1 hour, and only 57.5 per cent were dead at the end of 24 hours. With a formulation containing 20 per cent DDT the knockdown at the end of one hour was 54.5 per cent with 100 per cent of the beetles dead at the end of 24 hours.

The amount of DDT contained in the formulation also regulated the distance from the applicator at which beetles were killed.

SWATH WIDTH.—The amount of efficient work that can be done in a fogging operation in a given period of time will depend on the width of the swath in which beetles are killed. Fast drifting fogs are relatively inefficient, therefore the per cent DDT and fogged at the rate of 35 gallons per hour, successful kill on Japanese beetles was obtained in swaths extending 100 feet in the horizontal direction and covering heights in the perpendicular up to 15 feet. Where beetles were infesting high bushes or trees, it was necessary to stop, momentarily, near the base of the tree and direct the fog into the tree. Fogs containing 7.5 to 10 per cent DDT were generally inefficient at distances greater than 50 to 60 feet away from the machine.

It is not intended to infer that beetles will not be killed by fogs of the above concentrations at greater heights or greater distances, but the distances given do closely approach those found for effective operation. Even within the ranges stated "blind spots" in which beetles are not killed may occur. Wind currents and buildings often deflect the fog and bring about these blind spots.

With either airplanes or conventional

sprayers the writers have noted that good kills on Japanese beetles are not obtained when less than 1 pound of actual DDT is contained in a formulation or mixture to be applied to one acre. When airplane or conventional methods are used, our recommendation is that a minimum of 1 pound of DDT be applied to each acre treated. Calculations indicate that this formula may be useful in preparing concentrations for fogging. Table 1 shows that traveling at the rate of 4 miles per hour and dispersing 35 gallons of insecticide, the area or swath width in which approximately 100 per cent of the beetles were killed bears a rather definite relation to the amount of DDT in the formulation. With a formulation containing 7.5 per cent DDT the distance or swath width is approximately 30 feet. As the DDT content of the formulation is increased the area over which approximately 100 per cent kill is obtained increases. With a formulation containing 20 per cent DDT the swath widens to 100 feet.

Table 2.—Efficiency of corase fogs (particle size 40 to 60 microns) for killing Japanese beetles, showing the relationship between acreage covered (based on dog depths in which 95 to 100 per cent of all beetles were killed) and the amount of DDT in pounds used.

WIDTH OF SWATH IN DISTANCE COVERED	AREA COVERED, ACRES	LBS. DDT USED	PER CENT OF BEETLES KILLED	PER CENT OF DDT IN FORMULATION
30 ft.	14.7	18.0	100.00	7.5
60 ft.	29.0	24.5	96.7	10.0
60 ft.	29.0	36.7	99.0	15.0
100 ft.	48.4	36.7	97.5	15.0
100 ft.	48.4	49.0	100.0	20.0

Table 2 shows the total acreage that would be treated on the basis of these different swath depths, the total number of pounds of DDT dispersed in treating the area and the efficiency of the fogs for killing beetles.

It will be noted that 100 per cent Japanese beetle kill was not obtained over a 100 foot swath until a 20 per cent DDT mixture was used. With a 100 foot swath the fog machine killed beetles on approximately 48.4 acres. The amount of DDT dispersed in the treatment was 49 lbs. This same relative proportion seems to hold for the other swath widths. A 10 per cent solution gave 96.7 per cent kill at 60 feet. This swath width covered approximately 29 acres and the amount of DDT used was approximately 24.5 pounds.

CONCLUSION.—Aerosol fogs containing DDT may be used to control the Japanese beetle provided meterological conditions, fog particle size, and the formulation being dispersed are coordinated and in proper adjustment. Fast drifting fogs are not effective for killing beetles. Best results are obtained under conditions of calm that permit the fog to engulf the area under treatment and hold without rapid dissipation. Fine or dry fogs are relatively inefficient. Coarse or wet fogs are required. The swath width over which a given fog will kill beetles is dependent in a large measure on the amount of DDT contained in the formulation being dispersed. Rich insecticide mixtures are much more effective and desirable than those containing relatively small amounts of insecticides. Where high bushes or trees are involved it is necessary to approach close to the base of the tree, stop momentarily and direct the fog into the tree. In preparing formulations for fogging to effectively kill Japanese beetles it appears necessary to use sufficient DDT so that a minimum of 1 pound will be dispersed for each acre treated. With a formulation containing 20 per cent DDT it was possible in these experiments to kill Japanese beetles at a distance of 100 feet from the point at which the fog was liberated.

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Control of the Lettuce Yellows Disease in New York[1]

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The control of the lettuce yellows disease in New York is at present primarily an entomological problem as the virus has been shown to be transmitted in the field in this state only by the six-spotted leafhopper, *Macrosteles divisus* (Uhl.). Although the disease was reported in New York as early as 1921 by Coons (1922), and has been of considerable importance in the principal lettuce growing areas since that time, field control has not been extensively practiced because of the lack of measures which could be relied upon to give satisfactory or economical results. Average annual losses in the state up to 1939 were estimated by Linn (1940) at from 5 to 6 per cent. Losses from 1939 to 1946 averaged considerably higher than these figures, and in Oswego, Genesee and Orange counties where most of the research reported in this paper was conducted, losses have been estimated by the present writers at over 50 per cent for 1946, and slightly under this figure for 1947. In both of these years complete loss of individual fields was quite common.

Pyrethrum and rotenone dusts containing sulphur gave good results in tests conducted by Pepper & Haenseler (1939) in New Jersey. Similar dusts gave practical control on transplanted lettuce crops on Staten Island as reported by Linn (1940). These materials have not met with success or wide-spread use on seeded lettuce crops in the muckland areas of New York. Where they have been tried, they have either failed to give any appreciable degree of control of the yellows disease or have given control only where more applications were made than were justified on the basis of financial returns from the crops. Results of preliminary tests of DDT aerosols against six-spotted leafhoppers were reported by Smith *et al.* (1945). A high mortality of these insects was obtained where the aerosols were used on head lettuce in an effort to protect the crop from further spread of the aster yellows virus.

FIELD CAGE TESTS.—Cloth fencing was used by Pepper & Haensler (1939) to exclude leafhoppers from lettuce and thus effect control of yellows. Likewise, cloth screens were used by Linn (1940) to exclude leafhoppers from lettuce grown in greenhouses and coldframes.

In 1942 and 1943 cages of various sizes were used on crops of muck-grown lettuce. Some cages were placed on portions of crops at seeding time and others at various successive stages of plant growth. A large cage without canopy was used on successive plantings in a plot 50 feet square. All tests with cages indicated that a high degree of yellows control can be obtained by such devices, but that much of the lettuce so grown is not marketable due to abnormal development and losses from fungus diseases. The most important information obtained from the tests with cages was an indication of the necessity for protection of the crop from viruliferous leafhoppers from the time of emergence of the plants until they are well over half grown.

Early experiments with DDT dusts, in which successive starting dates of applications were used, confirmed the necessity of early protection from insect feeding, and indicated that DDT might supply a large measure of this needed protection.

PHYTOTOXICITY.—In the numerous field tests included in the present report, up to eight applications of 5 per cent DDT dust at a rate of 100 pounds per acre per application, other applications of DDT concentrations up to 10 per cent, and applications of impregnated DDT dusts were employed. In none of them were any signs of phytotoxicity evident in spite of the fact that applications in most of the tests were started when the lettuce plants were barely large enough to make the rows distinct. Aerosol and spray applications containing DDT also failed to produce any toxic symptoms under field conditions.

RESIDUES.[2]—Among the first problems to arise in connection with the use of DDT on lettuce was that of the possibility of harmful residues being left on the crop at harvest. It was felt that regardless of

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[1] The majority of the data presented in this paper are also being presented by the senior author to the Graduate School of Cornell University in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

[2] Thanks are due Dr. L. B. Norton and his assistants of the Cornell Univ. Agr. Expt. Sta. for conducting all of the analyses reported in this paper.

the degree of control of yellows which might be obtained with this material, its use could not be justified if harmful amounts reached the consumer. Thus, in 1944, fifty half-grown Iceberg lettuce plants were staked out in 5 rows of 10 plants each. Very heavy applications of 3 per cent DDT dust were made to all 5 rows, a week later to 4 of the rows, etc, the last treatment being applied to a single row only 2 days before harvest. After harvest the heads were trimmed and separate residue analyses from surface washings were run on the trimmings and on the trimmed heads as they would be packed for market shipment. Some of the lettuce which had been treated four times was dehydrated, crushed, and washed in benzene to determine whether any DDT might have been absorbed by the plants. The results of the analyses, shown in table 1, indicate very strongly that from the use of 3 per cent DDT dust no appreciable residues of DDT should be encountered on the marketable portions of heads provided applications are terminated 3 weeks prior to harvest. Results from a larger replicated test conducted in 1945 verified this conclusion.

Table 1.—Residues of DDT on lettuce treated with 3 per cent dust.

Number and Dates of Applications	Trimmings,[1] P.P.M.	Trimmed Heads,[1] P.P.M.
5 (8/14, 8/21, 8/28, 9/5, 9/12)	358	211
4 (8/14, 8/21, 8/28, 9/5)	185	20
3 (8/14, 8/21, 8/28)	110	4
2 (8/14, 8/21)	12	0.2
1 (8/14)	4	0.2
4 (as above, dehydrated after benzene washing)		2.0

[1] All analyses run on lettuce harvested 9/14.

In a series of experiments in 1946, 3 per cent DDT dust was applied to lettuce crops at 14, 10, 7, 5 and 3-day intervals. Regular-grind, micronized and impregnated DDT dusts were also applied at weekly intervals. Dusts containing 1, 2, 3, and 10 per cent DDT, and sprays containing 0.125 per cent regular-grind and micronized wettable powders, were applied. Amounts of DDT applied ranged from 0.3 pound to 3.3 pounds per acre per application. In all experiments the applications were begun as soon as the lettuce plants emerged from the soil and were discontinued 2 to 3 weeks before harvest of the crop. The number of applications varied from 4 to 14. At harvest 10 heads were taken at random from each treated plot and from untreated check plots. The heads were weighed, pulled apart leaf by leaf, and dried to crispness in a greenhouse. Analyses by the Schechter & Haller colorimetric method revealed less than 1 p.p.m. of DDT residue on the sample of harvested lettuce from any treated plot.

In a single test, weekly applications of a 3 per cent DDT dust to lettuce plants in a small plot were continued until 2 days before harvest. Analysis of heads so treated showed 4.09 p.p.m. of DDT residue, again indicating that there is a danger of having considerable amounts of DDT on harvested lettuce if field applications are too long continued.

THE DDT DUSTING PROGRAM.—Most of the lettuce in New York is grown on peat, or muck, soil where insecticides can be applied most efficiently as dusts. The experiments described in this paper were conducted on Iceberg lettuce crops and were attempts to approach practical control under field conditions. Because leafhoppers are the only means of spread of the virus, the percentages of yellowed plants at harvest indicate indirectly the degree of leafhopper control, probably the upper levels of control. It should be noted that the incidence of yellowed plants normally rises steadily from mid-June through July and August, and that any value for a treated plot should be compared with adjacent checks of similar age. Results from series of treatments applied at different times during the growing season are not directly comparable. Leafhopper counts made by sweeping during the present series of investigations did not seem to give reliable or consistent evidence of leafhopper population or control and are therefore not included in this report.

Regular grind, mechanically-mixed DDT, diluted with fibrous talc or pyrophyllite, was applied with a 4 or 6-row self-propelled duster in several experiments on concentrations, rates of applications, and intervals between applications as shown in table 2. In the test on concentrations 1-acre plots were treated 5 or 6 times at weekly intervals, using 35 pounds

per acre per application. In the test on rate of applications, half-acre plots were treated 8 times at 5-day intervals with a DDT-pyrophyllite (5-95) dust. In the test on interval between applications, one-acre plots were treated with DDT-talc (3-97) dust applied at a rate of 35 pounds per acre per application.

Table 2.—Yellows incidence in lettuce treated with DDT dusts at various concentrations, rates and intervals between applications.

Treatment	Date of Harvest	Per Cent of Plants Yellowed
Concentrations:		
1% DDT	8/ 8/46	48
2% DDT	8/18/46	42
3% DDT	8/ 5/46	40
Check	8/ 5/46	76
10% DDT	9/11/46	33
Check	8/25/46	86
Rates		
35 lbs. per acre per application	8/22/47	25
100 lbs. per acre per application	8/22/47	14
Check	8/22/47	57
Intervals		
Check	7/21/46	29
14 days A (3)[1]	8/ 3/46	51
B (4)	9/ 4/46	34
10 days A (5)	8/ 2/46	27
B (3)	8/13/46	66
7 days A (5)	7/26/46	15
B (8)	9/14/46	36
5 days (10)	9/14/46	35
3 days (14)	9/12/46	23
Check	9/12/46	82

[1] Number of applications.

OTHER FORMULATIONS OF DDT.—In addition to the foregoing work with mechanically-mixed regular-grind DDT dust, several experiments were conducted with other formulations of this active ingredient. Results of these tests are given in table 3 and are grouped according to the tests in which the various formulations were included. (1) Regular-grind and micronized wettable powder were compared in 4 applications of 0.125 per cent sprays applied at a rate of 100 gallons per acre per application on replicated plots of 0.083 acre each. (2) A regular-grind 5 per cent DDT dust was compared with an aerosol containing 10 per cent DDT, 5 per cent cyclohexanone, 5 per cent oil,[1] 20 per cent acetone, 3 per cent pyrethrum[2] and 57 per cent methyl chloride. The aerosol was dispensed from a rig mounted on bicycle wheels which covered 7 rows and distributed the material in a fine mist. A canvas back-drop was used to reduce drift. Six applications were made at 5-day intervals. The dust was applied at a rate of 35 pounds per acre per application by means of self-propelled row-crop duster, and the aerosol was applied at a rate of 7.5 pounds per acre per application. (3) In 1946 a 3 per cent mechanically-mixed regular-grind dust was compared with an impregnated dust containing only 0.5 per cent DDT. Acre beds of lettuce were dusted 3 times at 2-week intervals beginning when plants had just emerged from the soil. In 1947 a 0.5 per cent impregnated dust was compared with a 5 per cent mechanically-mixed regular-grind dust. Seven applications of each material were made on plots of 0.375 acre each. (4) A regular-grind dust was compared with a micronized dust of equal content of active ingredient. Both dusts were mechanically mixed and applications were made with a self-propelled row-crop duster to adjacent acre beds of Iceberg lettuce. Applications were begun as soon as plants emerged from the soil and were repeated at 10 to 12-day intervals thereafter. Five applications of regular-grind dust were made, whereas only 4 were made with the micronized dust.

[1] *A.P.S. 202.*
[2] *Pyrethrum DW20.*

Table 3.—Yellows incidence in lettuce treated with various formulations of DDT.

Treatment	Date of Harvest	Per Cent of Plants Yellowed
(1) Spray, regular-grind DDT[1]	8/22/46	81
Spray, micronized DDT[2]	8/22/46	82
Check	8/22/46	91
(2) 5% DDT dust[3]	8/13/47	17
DDT-pyrethrum aerosol	8/13/47	20
Check	8/11/47	53
(3) 1946:		
0.5% impregnated DDT[4]	8/ 4/46	33
3.0% regular-grind DDT[5]	8/ 8/46	49
Check	8/18/46	88
(3) 1947:		
Check	8/21/47	59
0.5% impregnated DDT[4]	8/26/47	19
5.0% regular-grind DDT[5]	8/26/47	18
Check	8/29/47	68
(4) 3% regular-grind DDT[5]	9/ 4/46	36
3% micronized DDT[6]	9/10/46	35
Check	8/25/46	86

[1] *Gesarol AK-50.*
[2] *Cytox 50% Wettable.*
[3] *G.L.F. Dust #60.*
[4] *Dry Multicide.*
[5] *G.L.F. Dust #17.*
[6] *Dry Multicide F-570.*

OTHER MATERIALS.—In the following series of experiments, various dust formulations of pyrethrum, rotenone, sulphur, etc., with and without DDT, were applied by means of a self-propelled row-crop duster at a rate of about 35 pounds per acre per application. Applications in each case were begun as soon as rows were well marked by germinating plants, and were continued until heads had begun to form. At harvest the counts of yellowed heads were taken in all treated beds, and in adjacent untreated beds for comparison. Dust formulations were prepared in either a mixing drum or an agitator-type dust mixer. Results, grouped according to the comparisons made in these tests, are given in table 4. (1) Five applications of dusts containing 3 per cent DDT and 3 per cent of the dimethoxy analog of DDT (dimethoxyphenyl trichloroethane) were compared on adjacent 1-acre beds of Iceberg lettuce. Fibrous talc was used as the diluent. Applications were made at 10-day intervals. (2) A dust containing 0.3 per cent pyrethrins, 30 per cent sulphur and 20 per cent pyrophyllite was compared with a DDT-pyrophyllite (5-95) dust, and with a dust containing 1 per cent rotenone, 30 per cent sulphur and 47.5 per cent pyrophyllite. Adjacent 1-acre beds were given 9 applications at 5-day intervals. Included in this experiment was also a dust which in addition to pyrethrum, sulphur and pyrophyllite, contained 5 per cent DDT. (3) An impregnated dust containing 0.5 per cent DDT plus 0.06 per cent pyrethrins was compared with one containing 0.5 per cent impregnated DDT alone, and with a

Table 4.—Yellows incidence in lettuce treated with various DDT, pyrethrum, rotenone and sulphur dust formulations.

TREATMENTS	DATE HARVESTED	PER CENT OF PLANTS YELLOWED
(1) DDT-talc (3-97)	9/ 4/46	36
Dimethoxy analog-talc (3-97)	9/ 1/46	47
Check	8/25/46	86
(2) Check	7/28/47	51
Pyrethrins[2]-sulphur-pyrophyllite (.3%-30%-balance)	8/ 7/47	31
DDT-pyrophyllite (5-95)	8/12/47	23
Rotenone-sulphur-pyrophyllite (1%-30%-balance)	8/22/47	45
DDT[1]-pyrethrins[2]-sulphur-pyrophyllite (5%-.3%-30%-balance)	8/17/47	20
Check	8/30/47	56
(3) Check	8/1 /46	64
DDT-pyrethrins-talc (0.5%-0.06%-balance), impregnated	8/14/46	60
DDT-talc (0.5%-balance), impregnated	8/ 4/46	33
DDT-talc (3-97) mechanically-mixed	8/ 8/46	49
Check	8/18/46	86
(4) DDT[3]-pyrophyllite (0.5%-balance), impregnated	8/26/47	18
DDT[4]-pyrethrins-pyrophyllite (0.5%-0.06%-balance), impregnated	8/23/47	21
DDT[5]-pyrethrins-pyrophyllite (0.5%-0.06%-balance), impregnated	8/23/47	22
DDT-pyrophyllite (5-95), mechanically-mixed	8/26/47	19
Check	8/26/47	59
Check	8/29/47	68
(5) DDT-pyrophyllite (5-95)	8/11/47	19
	8/15/47	21
DDT-sulphur-pyrophyllite (5-30-65)	8/11/47	24
	8/15/47	21
DDT-pyrethrins[2]-sulphur pyrophyllite (5%-.3%-30%-balance)	8/11/47	27
	8/26/47	25
Checks	8/15/47	65
	8/22/47	54

[1] From *Genitox S-50.*
[2] From ground flowers containing .6% pyrethrins.
[3] From *Double Strength Dry Multicide F-570.*
[4] From DDT-*Pyrethrum Dust Concentrate F-514.*
[5] From *Double Strength DDT-Pyrethrum Dust Concentrate F-571.*

mechanically-mixed dust containing 3 per cent DDT. Four applications were made on 1-acre beds at 2-week intervals. (4) Three impregnated dusts containing 0.5 per cent DDT were compared with each other and with one non-impregnated dust containing 5 per cent DDT. (5) A test of DDT-pyrophyllite (5-95) dust, DDT-sulphur-pyrophyllite (5-30-65) dust, and DDT-pyrethrins-sulphur-pyrophyllite (5-0.06-30-balance pyrophyllite) was conducted on replicated half-acre plots. Seven or eight applications of these various dusts were made at 5-day intervals. For each dust two replicates were employed and the results obtained from them are given separately in the table.

DISCUSSION OF RESULTS.—Under field conditions in New York, the problem of residue of DDT on dusted head lettuce was not found to be a limiting factor in the use of this material. In all experiments in which applications of DDT dusts and sprays were discontinued as long as 3 weeks prior to harvest, the residues found on the heads as sent to market were far under the arbitrary tolerance of 7 p.p.m. It might be pointed out that applications of insecticides immediately prior to harvest are of little benefit from the standpoint of control of yellows in the particular crop treated because healthy plants inoculated with the virus this late do not have sufficient time to produce visible symptoms.

As a general rule the application of DDT dusts resulted in approximately 50 per cent reductions in the incidence of yellows. The reductions obtained in 1947 were greater than those in 1946 due primarily to more complete information on the concentrations, rates, and timing of applications. Also contributing to this difference may have been the fact that in 1947 the leafhopper populations and the incidence of yellows were both somewhat lower than in 1946.

While best results were obtained from the use of dusts containing as much as 10 per cent DDT, they were not sufficiently better than results obtained with dusts of somewhat lower concentrations to justify their recommendation. Tests conducted for other purposes showed that almost as good results could be obtained from use of a lower concentration applied more frequently to keep new growth covered. In some instances dusts containing 3 per cent or less of the active ingredient failed to give consistent results, so a content of 5 per cent was selected for further experimental work and for suggested use by growers. It also appeared that better results were obtained from the use of heavier applications of the 5 per cent material than are normally made with dusts on row crops, but they were not considered sufficiently better than applications of 35 to 40 pounds per acre per application to justify their increased cost. Further, it was found in tests not reported in the present writing, and from numerous observations of commercial use of dust, that, in general, applications started when the lettuce was barely large enough to mark the rows distinctly, and repeated at short intervals, produced better results than did those in which high concentrations or heavy doses alone were stressed. An interval of 5 days between applications proved to be the most satisfactory in keeping new growth covered while at the same time keeping the dusting program workable on a commercial basis.

The tests so far conducted with various formulations of DDT have revealed none superior to a 5 per cent, regular-grind, mechanically-mixed dust. Sprays were were not extensively investigated because of the weight limitations involved. In a single test of sprays, neither regular grind wettable powder nor micronized wettable powder gave any appreciable control of yellows, although their failure can most likely be attributed to the small size of the experimental plots.

An aerosol containing a high percentage of DDT plus pyrethrum gave control comparable to that obtained from a 5 per cent dust. Whether this manner of applying the active ingredients can be made economical under New York conditions depends upon future research on lower concentrations and cheaper propellents.

The most interesting result obtained from work with the various formulations of DDT was that of the effectiveness of the impregnated dusts tested in 1946 and 1947. In both of these years impregnated dusts containing only 0.5 per cent DDT gave as good reductions in incidence of yellows as did the 3 per cent or 5 per cent regular-grind, mechanically-mixed dusts with which they were compared. As already indicated, none of these materials left any appreciable residues of DDT at harvest.

In a single test in which a regular-grind DDT was compared with a micronized material of equal content of active ingredient, the results obtained were almost identical; both materials gave better than 50 per cent reductions in yellows. In another test, a dimethoxy analog of DDT gave a fair degree of control of yellows, but it did not equal the effectiveness of the DDT.

Extensive tests conducted during the past two years showed no benefits from the addition of sulphur or pyrethrum to the mechanically-mixed DDT dust. Neither did combinations of rotenone and sulphur, or pyrethrum and sulphur, without DDT give as marked reductions in yellows as did DDT alone.

In the summer of 1947, a series of 7 beds averaging from 1 to 2 acres in size, but not planted in regular succession, were dusted with 5 per cent DDT applied at 5-day intervals up to within 3 weeks of harvest. It was observed that beds which were still being dusted on both sides of a bed approaching harvest, or being harvested, acted as treated barriers to cut down the numbers of leafhoppers surviving after migration from the older bed. In support of this observation it was evident that a higher degree of control of yellows was obtained in the plantings of mixed ages than was generally obtained in those in regular succession. It was also observed that each harvested bed of lettuce contained numerous uncut rejected plants, many of which were yellows-infected. These plants served as hosts to vast numbers of leafhoppers which were forced to migrate as a result of disking operations. The numbers of insects migrating were greatly reduced by thoroughly dusting the beds with 5 per cent DDT after harvest but before disking of the crop residue. Where mixed plantings and clean-up dust applications were employed conclusive data were difficult to obtain, but both practices appeared to be worthy of further investigation.

AIRCRAFT APPLICATIONS.—Two 4-acre blocks of lettuce were treated with 5 per cent DDT dust at approximately 5-day intervals by a fixed-wing plane[1] and by an agricultural model helicopter.[2] The blocks were broken into four beds each for convenience in planting and harvesting. Six applications at an approximate rate of 35 pounds per acre per application were made with the fixed-wing plane, and ten or eleven applications with the helicopter. The four beds treated by fixed-wing plane contained an average of 15 per cent yellowed plants as compared with an average of 24 per cent in the beds treated by the helicopter. The difference observed may have been due to the fact that while the fixed-wing plane applications were started a little later than those by helicopter, they were made on earlier planted lettuce which would normally be expected to contain fewer yellowed plants at harvest. The most important observation made during the course of the test was that, despite the lack of a nearby untreated check for direct comparison, untreated fields in the general area in which the tests were conducted ran probably twice as high in incidence of yellows.

[1] *Stearman P.T. 17.*
[2] *Bell Aircraft Corp.*

SUMMARY.—As a result of preliminary tests on the cloth screening of lettuce from attack by six-spotted leafhoppers, it was found that protection was necessary from the time of emergence of plants until they were well over half-grown in order to effect any appreciable control of the yellows disease. DDT in the form of a mechanically-mixed dust proved effective when applied throughout this period.

The most effective and economical dusting program developed from the numerous field tests was one in which 5 per cent DDT dust was applied at a rate of 35 pounds per acre per application when applications were begun as soon as the lettuce rows were well marked by germinating plants and were repeated at 5-day intervals to within an estimated 3 weeks of harvest.

Various other formulations of DDT were subjected to field tests but none of them proved superior to the regular-grind, mechanically-mixed dust. Outstanding among the formulations tested were the dusts in which the DDT in solution was impregnated on a carrier before being mixed with a diluent. Impregnated dusts of DDT content of only 0.5 per cent gave results comparable to those obtained with the 5 per cent dry-mixed material.

No benefits were derived from the addition of sulphur or pyrethrum to the mechanically-mixed dusts. Neither did rotenone and sulphur, or pyrethrum and sulphur, prove as effective without

DDT as did the DDT when used alone.

The use of regularly-dusted plantings of lettuce beds in which adjacent crops had an age differential of approximately 3 weeks, together with an application of 5 per cent DDT dust between harvesting and disking operations, appeared to possess considerable merit.

In a single test in which aircraft were used to apply DDT dust both a fixed-wing plane and a helicopter proved effective.

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Insecticidal and Phytotoxic Properties of Plant Dips Used to Control the European Chafer

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The practicability of controlling larvae of the European chafer *Amphimallon majalis* Raz. in lawns and similar turf areas through the use of residual soil treatments has already been demonstrated (Gambrell 1946). A safe and efficient treatment is also desired for balled and burlapped nursery stock in order to prevent dissemination of the pest. Preliminary experiments indicated that third-instar larvae were susceptible to ethylene dichloride when this was used as a plant dip on balled and burlapped nursery stock (Gambrell 1942). Later studies (Gambrell 1945; Mason 1945) demonstrated that dips containing ethylene dichloride either alone or in combination with ethylene dibromide were quite toxic to larvae but the latter material caused injury to some species of plants if used during the growing season.

The object of the studies reported here was to determine the relative effectiveness of various concentrations of ethylene dichloride, ethylene dibromide, or a combination of these chemicals, on grubs of the European chafer when used as plant dips on balled and burlapped nursery stock, on bare oils or seed beds as a surface application, and the possible phytotoxic effect of these materials on various species of evergreens.

MATERIALS AND METHODS.—The materials used in this series of tests were ethylene dichloride, ethylene dibromide and chlordane. Ethylene dichloride was used in the form of an emulsible mixture which contained 97.5 per cent by weight of active ingredient and 2.5 per cent of a surface-active agent (a polyoxyalkylene derivative of sorbitan monolaurate).[3] Ethylene dibromide was also used as an emulsible mixture containing 16 per cent by weight of ethylene dibromide, 81.5 per cent of ethylene dichloride and 2.5 per cent of the wetting agent.[1] The effectiveness of both of these mixtures for the control of Japanese beetle larvae has been demonstrated (Mason *et al.* 1943; 1946). Their preparation and use have also been described (Chisholm *et al.* 1944, 1946). Chlordan was used as an emulsible mixture containing 15 per cent by weight of chlordan, 82.5 per cent of ethylene dichloride and 2.5 per cent wetting agent,[1] These various mixtures were further diluted with water at rates indicated in tables 1 to 3.

The plant materials were supplied by the nurserymen who cooperated in this

Eastern Branch Program.

[1] Journal paper No. 736, New York State Agricultural Experiment Station, Geneva, N. Y.

[2] The work reported here was conducted under a cooperative arrangement between the United States Department of Agriculture, Bureau of Entomology and Plant Quarantine and the New York State Agricultural Experiment Station.

[3] *Tween 20.*

project. Trees were dug, balled, burlapped and handled according to regular nursery practices. These plant balls averaged about 8 to 10 inches in diameter. For the insect toxicity studies the plant balls were artificially infested with a known number of third-instar larvae (usually 20 to 25, depending upon the size of the ball) by punching holes through the burlap and inserting one grub in each opening, plugging the entrance and allowing the infested trees to remain in the packing cellar several days prior to dipping. These soil balls were dipped for 10 seconds in the solution containing the fumigant, allowed to drain 1 to 2 minutes and kept in compact groups on the floor of the nursery packing cellar or refrigerated room at a predetermined temperature and exposure period. The checks were dipped in water and similarly handled. Following this the plant balls were broken down, grubs removed and placed in 2-ounce partitioned salve tins containing soil and grass seed. Records on grub mortality were taken at weekly intervals over a period of 3 weeks and the data given in tables 1 and 2 represent accumulated mortality.

Table 1.—Mortality of *Amphimallon majalis* larvae in plant balls which were dipped under various conditions in ethylene dichloride, in a mixture of ethylene dichloride and ethylene dibromide, and in water alone.

Date 1946	Dosage Ml. per Gal.	Exposure, Days	Temperature °F.	No. of Balls	No. Grubs Recovered	No. Dead 3 Weeks	Per Cent Mortality 3 Weeks
			97.5% ethylene dichloride				
4/ 6	20	2	50	5	114	110	96.5
4/11	20	1	50	4	114	113	99.1
4/12	20	5	50	4	102	100	98.0
4/19	30	1	60	5	169	168	99.4
4/22	30	2	57	4	163	163	100.0
4/29	30	1	40	6	171	164	95.9
4/29	30	2	40	8	211	210	99.5
5/21	30	1	40	7	164	157	95.7
5/21	30	2	40	7	165	165	100.0
			16% ethylene dibromide				
4/ 6	2.5	2	50	5	108	102	94.4
4/11	2.5	1	50	4	111	107	96.4
4/12	2.5	5	50	4	129	129	100.0
4/19	5.0	1	60	5	174	174	100.0
4/22	5.0	2	57	5	162	162	100.0
4/29	5.0	1	40	6	176	176	100.0
4/29	5.0	2	40	7	219	218	99.5
5/21	5.0	1	40	7	159	158	99.4
5/21	5.0	2	40	7	165	165	100.0
6/17	2.0	6	70	10	203	203	100.0
6/17	2.0	5	40	8	204	204	100.0
6/17	1.0	6	70	8	189	188	99.5
6/19	1.0	5	40	7	181	181	100.0
			Checks—Dipped in water				
4/ 6	—	2	50	6	100	23	23.0
4/11	—	1	50	5	110	25	22.7
4/12	—	5	50	4	116	52	44.8
4/29	—	1	40	5	139	25	18.0
4/29	—	2	40	5	131	24	18.3
5/21	—	1	40	4	97	40	41.2
5/21	—	2	40	4	96	39	40.6
6/17	—	6	70	4	82	34	41.5
6/17	—	5	40	5	94	26	27.7

For the surface application test plots 1 square yard in area located in an empty seed bed, were infested with third-instar larvae at the rate of 200 per square yard. After standing for 5 days these plots were treated with various materials, using 1 gallon of the diluted mixture per square yard, and digging records on grub mortality were obtained 11 days later.

Following this the grubs were held in salve tins as described above. In the plant injury tests uninfested plant balls were treated in the same manner as described in the grub toxicity studies above but the trees were planted out in the nursery row after 24 hours. The soil and burlap were allowed to remain around the roots.

RESULTS WITH PLANT DIPS.—Grub mortality records are given in table 1. It will be observed that both ethylene dichloride and ethylene dibromide were used at several concentrations and temperatures and that the trees were held for different periods following treatment. For the most part, the highest mortality occurred during the week following treatment; also the higher concentrations, longer exposure periods and higher temperatures appeared to favor higher grub mortality.

Ethylene dichloride, when used as a plant dip at the rate of 30 ml. per gallon, showed somewhat higher grub mortality at the end of the 3 weeks when the plant balls were held during the post-dipping period at 60° F. than when held at 40° F. The mortality of grubs from the 30 ml. concentration was about the same when held for 48 hours at 40° F. as compared with the same treatment with an exposure period of 24 hours at 60° F. Table 1 also shows that in only 2 out of 9 tests did ethylene dichloride give complete kill and in both instances the 30 ml. per gallon dosage was used. In no case did the 20 ml. concentration give complete control in these particular tests. A holding period of 5 days following fumigation did not show an appreciable increase in mortality over the 2-day period. From a total of 1373 grubs used in several tests at 20 ml. and 30 ml. per gallon the per cent mortality ranged between 95.7 and 100.

Ethylene dibromide when used at 2.5 ml. per gallon was practically as effective as 20 ml. of ethylene dichloride. Also grubs were killed more rapidly than when ethylene dichloride was used alone. A total of 13 groups of plant balls, involving 2180 larvae, were dipped in ethylene dibromide at concentrations of 1 ml., 2 ml., 2.5 ml., or 5 ml. per gallon. Grub mortality varied from 99.4 to 100 per cent for the 2.5 ml. dosage, 100 per cent for the 2 ml. dosage and 99.5 to 100 per cent for the 1 ml. dosage after 3 weeks. Concentrations of 5 ml. or higher per gallon proved quite toxic to plants (Table 3).

RESULTS OF SURFACE APPLICATIONS.—Surface applications were made in an effort to determine the possibility of controlling grubs in seed beds and as a means of disinfesting large plants in the nursery row prior to digging. Preliminary experiments conducted during 1945 indicated that the application of 10 ml. of ethylene dibromide per gallon per square yard on bare ground, weed plots, grass plots and turf gave from 82.9 to 100 per cent control of third-instar larvae 3 weeks after application. Fully grown third-instar larvae proved more difficult to kill than younger third-instar larvae.

Table 2.—Mortality of *Amphimallon majalis* larvae in soil plots (seed beds) three weeks after treatment with different concentrations of ethylene dibromide and of chlordane. Treatment was made June 24 and plots dug July 5, 1946 for recovery of various stages.

Plot No.	Concentration Ml./Gal. per Sq. Yd.	Total Recovered	No. Pupae	No. Prepupae	No. Larvae Alive	No. Larvae Dead	Per Cent Mortality[1]
			16 per cent ethylene dibromide				
1	20	83	0	0	0	83	100.0
2	20	102	0	0	0	102	100.0
3	10	80	0	3	1	76	95.0
4	10	101	0	0	0	101	100.0
			15 per cent chlordane mixture				
5	20	123	25	83	0	15	12.2
6	10	126	80	30	0	16	12.7
7	10	105	66	16	0	23	21.9
8	5	135	107	12	1	15	11.1
			Check				
9	—	102	86	13	1	2	1.9

[1] Accumulated mortality of larvae 3 weeks after treatment.

Soil type and moisture conditions appeared to be factors affecting grub control both in plant ball dips and in soil which received a surface application. Data presented in table 2 shows that concentrations of both 20 ml. and 10 ml. of ethylene dibromide per square yard in replicated plots, produced 95 to 100 per cent grub mortality whereas similar concentrations of chlordane gave only 12.2 to 21.9 per cent mortality. Transformation of larvae to the pre-pupal and pupal stages was very noticeable in the chlordane plots while only one larva and 3 prepupae were observed in the ethylene dibromide plots.

RESULTS OF PLANT TOLERANCE TESTS. —In preliminary tests during 1945 it was shown that Douglas fir, concolor fir, Norway spruce, Japanese yew and pyramidal arborvitae were seriously injured by dips containing 10 ml. and 20 ml. per gallon of ethylene dibromide. The following kinds of seedling plants, 2 to 4 years old, located in the seed bed were treated during the summer months with concentrations of 10 ml. and 20 ml. per gallon per square yard of ethylene dibromide applied as a surface application without any visible injury:—White fir, concolor fir, white spruce, Colorado spruce, Black Hills spruce, white pine, Oriental arborvitae, purple barberry, *Rosa humilis*, and *Viburnum opulus sterilis*. In another test two trees each of Irish juniper, Norway spruce and concolor fir, 18, to 36 inches in height, were treated in the nursery row during the growing period by applying 1 gallon per square yard of a solution containing 10 ml., 20 ml. and 40 ml. of ethylene dibromide on the surface of the soil. No plant injury resulted from these treatments.

For the plant toxicity studies in 1946 groups of 25 trees each of Douglas fir, concolor fir, Colorado spruce, Japanese yew, mugho pine, Irish juniper and pyramidal arborvitae were dug, burlapped in 8 to 10-inch balls, dipped, and held in the packing shed for 24 hours prior to treatment as indicated in table 3. These trees were dipped on April 5, 1946, according to the same procedure as that used in the insect toxicity studies mentioned above. After 24 hours exposure the trees were planted in 3.5 foot rows with trees 3 feet apart. The soil and burlap were allowed to remain around the roots. Following this the trees received the same cultural practices as that of other plants in the nursery. A preliminary record as to condition of trees was obtained on July 10, 1946, approximately 3 months after planting; final records on plant injury were taken on August 11, 1947, the second year after treatment (Table 3).

Table 3.—Number of trees apparently normal the first and second year after being dipped in either ethylene dichloride or ethylene dibromide as used in experiments for control of *Amphimallon majalis*. Five trees of each species were used in each group. Trees dipped on April 5 and planted April 6, except Norway Spruce which was treated on June 17 and planted June 19, 1946.

Material	Concentration Ml. per Gal.	Douglas Fir		Concolor Fir		Colorado Spruce		Japanese Yew		Irish Juniper		Mugho Pine		Pyram. Arborvitae		Norway Spruce	
		1[1]	2[2]	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Ethylene dichloride	30	2	2	3	3	0	0	5	5	3	3	0	0	5	5	—	—
Ethylene dichloride	20	5	5	5	4	5	4	5	5	4	5	2	0	5	5	—	—
Ethylene dibromide	10	0	0	0	1	0	0	0	0	0	0	0	0	3	3	—	—
Ethylene dibromide	5	2	2	3	2	5	3	2	2	1	0	1	0	4	5	—	—
Ethylene dibromide	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	4
Ethylene dibromide	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	4
Check (dipped in water)	—	3	4	3	4	3	3	5	5	5	5	4	4	5	5	5	5

[1] = first year after treatment.
[2] = second year after treatment.

Another group of 15 Norway spruces was dug on June 14, 1946 during the growing period, and burlapped in 8-inch balls. They were held in the packing shed until treated on June 17. These trees were divided into groups of 5 trees each and were dipped in either one of the 2 concentrations of ethylene dibromide indicated in table 3, or in water, Trees were planted in the field on June 19 and handled according to the procedure described for the other treatments mentioned above.

Table 3 gives the data showing the

number of trees which appeared to be growing normally at two dates following the plant dip treatments. It will be observed that ethylene dibromide when used at the rate of 10 ml. per gallon proved quite toxic to all species of evergreens tested but that at the 5 ml. dosage more trees of all species survived or were less seriously injured. Bud scales on the Japanese yew and Irish juniper trees were just beginning to separate and show a trace of green color at the time of treatment. While other species displayed little or no visible evidence of new growth at the time of treatment, plant growth was observed on these same species of evergreens in the nursery shortly afterwards. The Norway spruce trees which were dug on June 14 during the growing period and dipped on June 17, 1946, in solutions containing either 1 ml. or 2 ml. per gallon of ethylene dibromide continued to grow normally, with the exception of one tree in each treatment. Considering that the growth of the 4 remaining trees in each treatment compared favorably with that of untreated trees it does not appear that ethylene dibromide at these latter concentrations was particularly injurious.

Plant injury varied both with the species of tree tested and with the material and concentration used. Some trees were retarded in growth, others turned brown in color and died within a few weeks. Figures 1 and 2 illustrate the variation in the amount of injury which occurred when Douglas fir trees were dipped in ethylene dichloride at 20 ml. and ethylene dibromide at 5 ml. per gallon. These conditions are fairly typical of all the species used in this experiment.

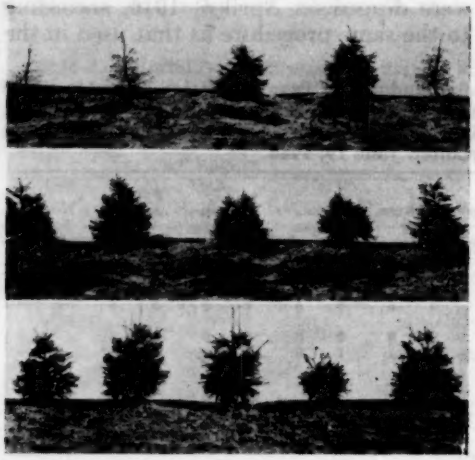

FIG. 1.—Condition of Douglas fir trees 18 months after treatment. *Top:* Dipped for 10 seconds in mixture of ethylene dibromide at rate of 5 ml. per gal. *Center:* Dipped for 10 seconds in mixture of ethylene dichloride at rate of 20 ml. per gal. *Bottom:* Check, dipped in water only.

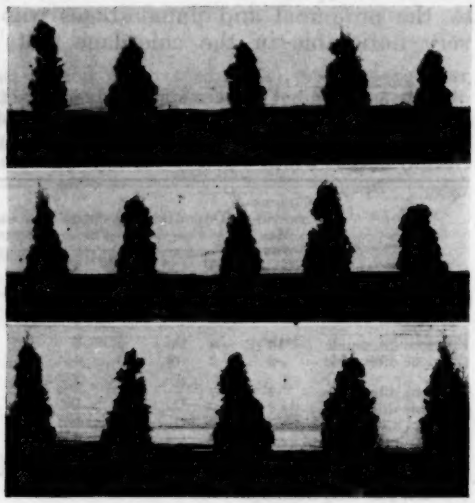

FIG. 2.—Condition of pyramidal arborvitae 18 months after treatment. *Top:* Dipped for 10 seconds in mixture of ethylene dibromide at rate of 5 ml. per gal. *Center:* Dipped for 10 seconds in mixture of ethylene dichloride at rate of 20 ml. per gal. *Bottom:* Check, dipped in water only.

SUMMARY.—A fumigant containing ethylene dichloride was used as a plant dip at concentrations of 20 ml. and 30 ml. per gallon for the control of third-instar larvae of the European chafer. At 20 ml. per gallon ethylene dichloride gave 96.5 to 98.0 per cent mortality and was not injurious to the trees. At 30 ml. per gallon 95.7 to 100 per cent mortality was obtained but complete control was observed in only two instances where the 30 ml. dosage was used. Likewise, more plant injury occurred. Ethylene dibromide was used at concentrations of 1, 2, 2.5 and 5 ml. per gallon in plant ball dips. At dilutions of 1, 2, and 2.5 ml. per gallon ethylene dibromide gave 94.4 to 100 per cent mortality. This is of particular interest since at concentrations of 5 ml. and 10 ml. this mixture proved quite toxic to a number of species of evergreens.

Ethylene dibromide when used at the

rate of 20 ml. or 10 ml. in 1 gallon per square yard as a surface application on soil gave 95 to 100 per cent control of third instar larvae. A chlordane-ethylene dichloride mixture when used at similar dosages gave from 12.2 to 21.9 per cent control. Further information is necessary to demonstrate the practicability of such a method of treatment for control of the European chafer.

Plant tolerance tests were conducted on 8 species of evergreens consisting of 5 trees in each treatment. All species, except Norway spruce, were dipped on April 4, 1946, in solutions containing either 30 or 20 ml. of the ethylene dichloride mixture or in either 10 or 5 ml. of the ethylene dibromide mixture. Norway spruce were treated June 17, 1946, with 1 and 2 ml. of ethylene dibromide per gallon of water. An equal number of each species of tree was also dipped in water. Ethylene dichloride at the 20 ml. concentration as a plant dip did not appear to affect the trees adversely while the 30 ml. dosage caused noticeable injury to all species except concolor fir, Japanese yew, Irish Juniper, and pyramidal arborvitae. Ethylene dibromide at both 5 ml. and 10 ml. dosages in dipping tests caused severe injury in most instances. Pyramidal arborvitae, when dipped in the 5 ml. concentration, had little or no visible injury. The 5 ml. concentration appears too toxic for general use as a plant dip on the plant species tested. It is recognized that 5 trees is too small a number on which to base recommendations with reference to plant injury and that further experiments are necessary to establish the practicability of using ethylene dibromide as a plant dip for the control of the European chafer. Nevertheless, on the basis of limited tests in which concentrations of 1 ml., 2 ml. and 2.5 ml. of ethylene dibromide caused a high mortality of third instar larvae, coupled with the fact that Norway spruce trees when dipped in concentrations of 1 ml. and 2 ml. per gallon showed a high survival, there is reason to expect that this material has possibilities. However, further experiments are necessary to establish definitely the possible role of ethylene dibromide as a plant dip on balled and burlapped evergreens for the control of the European chafer. Under the conditions tested ethylene dichloride at the rate of 20 ml. per gallon of water shows definite promise as a safe and effective treatment for the control of European chafer larvae in balled and burlapped nursery stock.

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KNIPLING RECEIVES MEDAL OF MERIT

Dr. E. F. Knipling, at present in charge of the Division of Insects Affecting Man and Animals of the Bureau of Entomology and Plant Quarantine, has been awarded the Medal of Merit by the Department of National Defense for his outstanding services during the war period. This supplements other awards received by Dr. Knipling and gives further emphasis to the work done by him and his associates which contributed so largely to the successful prosecution of the war.

Chlorinated Camphene for Control of Eastern Tent Caterpillar, Boxwood Leaf Miner and Bagworm[1]

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Parker & Beacher (1947) summarized developmental work on chlorinated camphene,[4] provided complete data covering its toxicity to several household pests, and presented a few facts indicating its possible value as an agricultural insecticide.

The status of chlorinated camphene in the field last-mentioned, was investigated further in 1947. Results, reported herein, include only those obtained in tests against the eastern tent caterpillar, *Malacosoma americana* (F.), the boxwood leaf miner, *Monarthropalpus buxi* Laboulb., and the bagworm, *Thyriodopteryx ephemeraeformis* (Haw.). Some consideration is given, also, to the phytotoxic effect of the sprays on ornamentals.

Eastern Tent Caterpillar.—These tests were conducted in a sizable area of wild cherry growth on farm land of the Worth Steel Company, Claymont, Delaware. A total of 200 representative trees, from 6 to 8 feet in height were selected to accommodate nine treatments and an unsprayed check of 20 trees each. The treatments included chlorinated camphene DDT, benzene hexachloride,[5] lead arsenate and lime (the usual control, as recommended by Wadley, 1947), and sulfur at five dosage-levels (to test the conclusions of MacLeod, 1937).

Hatching of this insect commenced April 12. Treatments were applied April 23. Control data (as total active nests) were recorded April 30, May 9 and 16. On the treatment date, larvae were 0.25 inch in length, nests varied from 2 to 3 inches in size and averaged 6.25 per tree; on April 30, larvae were 0.5-inch in length and nests varied from 4 to 5 inches in size; on May 9, larvae varied from 1 to 1.25 inches in length and nests varied from 8 to 10 inches in size; and on May 16, larvae were full-grown and migrating. Results are given in table 1.

Both chlorinated camphene and DDT (1 lb. to 100 gals.) gave 100 per cent control within a week; lead arsenate and lime (3 lbs. & 6 lbs. to 100 gals.), 100 per cent, and benzene hexachloride (3 lbs./100 gals.), 98 per cent within 2 weeks; and sulfur (6 to 30 lbs. to 100 gals.), no more than 95 per cent within 3 weeks. The action of sulfur at all five dosages was too slow to prevent extensive feeding.

Boxwood Leaf Miner.—Specimen box on the grounds of Friends School, Wilmington, Delaware, and on three estates in the suburbs (Greenville) of that city were treated on May 12 with chlorinated camphene, DDT, benzene hexachloride and molasses-nicotine sulphate (for many years, the standard control-combination; Weiss & Baumhofer, 1940).

The foliage of this box was moderately to thickly inhabited by this insect, with all miners in the pupal stage. Ten samples of 100 leaves each averaged 67 per cent infested and 3.6 miners per leaf. Emergence occurred between May 14 and 19. Control data, as recorded on September 29 by examination of 10 additional samples of 100 leaves each, are presented in table 1.

Chlorinated camphene and DDT (both at the rate of 2 lbs. to 100 gals.) and the molasses-nicotine sulphate combination, as well, gave 100 per cent control. At the reduced rate of one pound per 100 gallons, DDT proved slightly less effective and chlorinated camphene decidedly less effective. Results with benzene hexachloride were unsatisfactory. The molasses-nicotine sulphate combination is, obviously, almost prohibitive in cost.

Bagworm.—Sycamores, 50 feet or more in height near Centerville, Delaware,

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[2] Research Professor, Entomology; Temporary Assistant Entomologist; and Hercules Research Fellow, Entomology, respectively.

[3] Several property owners (in Wilmington, Delaware, and vicinity), the Bartlett Tree Research Laboratories (Stamford, Connecticut), the F. A. Bartlett Tree Expert Company (Wilmington, Delaware, office), and the Diamond State Nurseries (Milford, Delaware) cooperated in providing plantings, equipment, and other facilities required for this research. The sprayer, made available (courtesy R. M. Viggars) for treatments to control the three insects listed above, was a large, high-powered unit used regularly by the Bartlett Company in commercial work in this district. It was operated, as usual, by their experienced personnel.

[4] *Toxaphene;* Trade mark of Hercules Powder Company.

[5] *Lexone;* duPont Company product, a "50% hexachlorocyclohexane insecticide composition; gamma isomer of hexachlorocyclohexane, 6%; other isomers, 44%."

were sprayed with chlorinated camphene DDT, benzene hexachloride, lead arsenate and soybean flour (a widely-published control mixture; Metcalf & Flint, 1939), and sulfur at two dosage-levels. These trees had been severely damaged by this pest in 1946 and the few which were left unsprayed in 1947, were again completely defoliated.

PHYTOTOXICITY.—Chlorinated camphene sprays were applied to 52 species of deciduous trees and shrubs (Table 2) and to 19 species of evergreens (Table 3). The sprays were applied with a compressed-air, knapsack sprayer[1] and were tested for phytotoxicity at 0.5, 1, 2, and 4 pounds of this insecticide per 100 gallons of water. When DDT was compared with chlorinated camphene it was used at the same rates.

Table 1.—Summary of spray tests against eastern tent caterpillar, boxwood leaf miner, and bagworm, Delaware, 1947.

Spray Materials	Rates and Cost		Extent of Control		
	Per 100 Gals.	Total	Eastern Tent Caterpillar	Boxwood Leaf Miner	Bagworm
Chlorinated camphene (Chlorinated camphene 25-W, 8 lbs.)	2 lbs.	$ 1.92		100% in one test	
(Chlorinated camphene 25-W, 4 lbs.)	1 lb.	.96	100% in one week	68% in one test	92% in first week 59% av. for four weeks
DDT (50-W, 4 lbs.)	2 lbs.	1.80		100% in one test	
(50-W, 2 lbs.)	1 lb.	.90	100% in one week	98% av. for three tests	64% in first week 22% av. for four weeks
Benzene hexachloride	3 lbs.	1.20	90% in one week 98% in two weeks	58% in one test 29% in one test	40% in first week 14% av. for four weeks
Lead arsenate	3 lbs.	$ .70	97% in one week 100% in two weeks		
Spray lime	6 lbs.	.06 .76			
Lead arsenate	6 lbs.	1.41			100% in first week 61% av. for four weeks
Soybean flour[1]	4 oz.	.05 1.46			
Molasses	20 gals.	28.00		100% in one test	
Nicotine sulfate 40%	1 qt.	2.76 30.76			
Sulfur[2]	6 lbs.	.435	91% in three weeks		0% in first week 6% av. for four weeks
Sulfur	12 lbs.	.87	91% in three weeks		
Sulfur	18 lbs.	1.305	92% in three weeks		
Sulfur	24 lbs.	1.74	95% in three weeks		0% in first week 18% av. for four weeks
Sulfur	30 lbs.	2.175	95% in three weeks		

[1] *Sulforon.*
[2] Spraysoy.

When sprays were applied on July 14, the young bagworms averaged 0.25 inch in length. Control data were recorded both from observations on the extent of feeding on the trees and from mortality noted in weekly cage-tests commencing July 15, 24 and 30 and August 6. Results are included in table 1.

Only two treatments proved adequate—the lead arsenate-soybean flour mixture and the chlorinated camphene. In the cage-tests, lead arsenate effected 100, 68, 40, and 36 per cent control, with an average of 61 per cent for the 4-week period. Similarly, chlorinated camphene effected 92, 60, 48, and 36 per cent control, with an average of 59 per cent. These data check closely with the degree of foliage injury in each case.

On May 15, all trees in the New Arboretum at the Bartlett Tree Research Laboratories, Stamford, Connecticut, were sprayed with chlorinated camphene, 25 per cent wettable powder, with 50 per cent water miscible, and with the solvent[2] and emulsifier[3] of the latter formulation. Branches of sugar maple and of Siberian elm trees in the Old Arboretum were likewise treated with chlorinated camphene and DDT.[4] Two silver poplar trees were sprayed with the 0.5 and 1-pound concentrations of chlorinated camphene 50 per cent water miscible formulation

[1] *Smith-Banner.*
[3] *Shell E-407.*
[2] *Tween G-1045.*
[4] *Deenate 50-W.*

to determine its effect on this oil-sensitive plant.

Table 2.—List of 52 trees and shrubs[1] included in phytotoxicity tests with chlorinated camphene, Bartlett Tree Research Laboratories, Stamford, Connecticut, 1947.

Apple	—Red Gravenstein
	—Russett
	—Transparent
Apricot	—Moor Park
Ash	—Mountain
Beech	—American
	—European
Birch	—Black
	—European White
	—Red
Buckeye	
Cherry	—Montmorency
Chestnut	—Bartlett
Coffee	—Kentucky
Crab	—Hyslop
Dogwood	—Flowering
Elm	—Siberian
Euonymus	—European
Gum	—Sour
	—Sweet
Hackberry	
Heartnut	
Hornbeam	
Locust	—Honey
Magnolia	—Tripetala
Maple	—Hodge
	—Red
	—Striped
	—Sugar
	—Tartarian
Oak	—Basket
	—Post
	—Turkey
Peach	—Golden Jubilee
	—South Haven
Pear	—Beurre Bosc
	—Beurre D'anj'ou
	—Douglas
Plane	—London
Plum	—Bradshaw
	—Burbank
	—Imperial Gage
Poplar	—Silver
Quince	—Orange
Redbud	—American
Shadblow	—Downy
Silverbell	
Sophora	
Walnut	—Black
Willow	—Black
	—Golden
	—Laurel

[1] Reference for common names—Manual of Cultivated Trees and Shrubs, by Alfred Rehder, The Macmillan Company, 1934.

Most trees had broken dormancy and tender new growth was present. Exceptions were sour gum, hackberry, heartnut, black walnut, sophora, honey locust, Kentucky coffee, and redbud. Therefore, those not in leaf on May 15 were resprayed on May 28.

A minimum of 33° and a maximum of 54° F. were recorded on the application date, and temperatures ranged within these limits throughout the duration of the test. The sprays dried rapidly.

On May 22, injury was observed as a definite burning of Imperial Gage Plum foliage for all concentrations of the chlorinated camphene 25 per cent wettable powder, and on May 28, leaf-drop had commenced in the case of the 2- and 4-

Table 3.—List of 19 evergreens[1] included in phytotoxicity tests with chlorinated camphene, Diamond State Nurseries, Milford, Delaware, 1947.

Arborvitae	—Baker
	—Bonita
	—Globe
	—Golden (Peabody)
	—Golden (plain)
	—Oriental
	—Pyramidal
	—Siberian
Box	—Dwarf
Crytomeria	—Japanese
Fir	—Douglas
Juniper	—Irish
	—Pfitzer
	—Savin
Pine	—Scrub
Privet	—California
Retinospora	—Plume
Spruce	—Colorado Blue
Yew	—Japanese

[1] Reference for common names—Cultivated Evergreens, edited by L. H. Bailey, The Macmillan Company, 1923.

pound treatments. Also, on that date, marginal burning of the leaves of sugar maple was noted where branches had been sprayed with the above-mentioned dosages. No injury was apparent from the use of chlorinated camphene sprays on any other trees; no injury resulted from the May 28 respraying of trees not in leaf on May 15, and no injury occurred from the application of DDT sprays on sugar maple and Siberian elm.

On August 25, an evergreen planting at the Diamond State Nurseries, Milford, Delaware, was sprayed with the four concentrations of chlorinated camphene 25 per cent wettable powder previously mentioned. During the test period, temperatures ranged from 78° to 92° F., with a high humidity. The soil was very dry. All species treated proved tolerant to chlorinated camphene deposits, and no

injury was apparent from the single application.

These tests indicate that chlorinated camphene may be applied with safety at the concentration of 1 pound per 100 gallons of water to trees and shrubs, both deciduous and evergreen, which are commonly present in ornamental plantings.

SUMMARY.—In Delaware, during 1947, chlorinated camphene was tested against the eastern tent caterpillar, *Malacosoma americana* (F.), the boxwood leaf miner, *Monarthropalpus buxi* Laboulb., and the bagworm, *Thyridopteryx ephemeraeformis* (Haw.). DDT, benzene hexachloride, sulfur at several dosages, and the recommended controls for these three insects (lead arsenate and lime for eastern tent caterpillar; a molasses-nicotine sulphate combination for boxwood leaf miner; and lead arsenate and soybean flour for bagworm) were included in the tests for purpose of comparison.

Both chlorinated camphene and DDT (1 lb. to 100 gals.) gave 100 per cent control of eastern tent caterpillar on wild cherry growth within 1 week; and lead arsenate with lime (3 lbs. & 6 lbs. to 100 gals.), within 2 weeks.

Chlorinated camphene and DDT (both at the rate of 2 lbs. to 100 gals.) and the molasses-nicotine sulphate combination (20 gals. & 1 qt. to 100 gals.) as well, gave 100 per cent control of boxwood leaf miner.

Chlorinated camphene and lead arsenate with soybean flour, gave approximately the same control of bagworm; 92 and 100 per cent, respectively, within 1 week; 59 and 61 per cent, respectively, over a 4-week period.

Foliage injury results frequently from the use of lead arsenate. The molasses-nicotine sulfate combination is almost prohibitive in cost. The obvious advantages of chlorinated camphene against these three pests are freedom from injury, low cost, rapid action, and complete control.

Chlorinated camphene sprays were applied to 52 species of trees and shrubs and to 19 species of evergreens commonly present in ornamental plantings. It was tested for phytotoxicity, on tender new growth in the spring (Connecticut) and under mid-summer conditions of high temperature and high humidity (Delaware), at 0.5, 1, 2, and 4 pounds per 100 gallons of water. It proved completely safe at these rates on all species, except two—Imperial Gage plum and sugar maple.

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S. W. HARMAN

Professor S. W. Harman died suddenly from a heart attack on March 17, 1948. No one realized that his heart was abnormal and he worked in the orchard on the day before his death. Professor Harman has been a regular contributor to the JOURNAL for many years and his article in this issue will mark the end of the series. A suitable obituary notice will be published in an early issue of the JOURNAL.

Liquefied Gas Aerosols to Control Bean Beetles[1]

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During the summer of 1947 the authors were offered approximately 400 acres[2] of string beans and 120 acres of bunch lima beans for experimental work with liquefied gas aerosols on the control of the bean leaf beetle, *Cerotoma trifurcata* (Foist) and the Mexican bean beetle, *Epilachna varivestis* Muls. The string beans were planted early in May, the lima beans late in June.

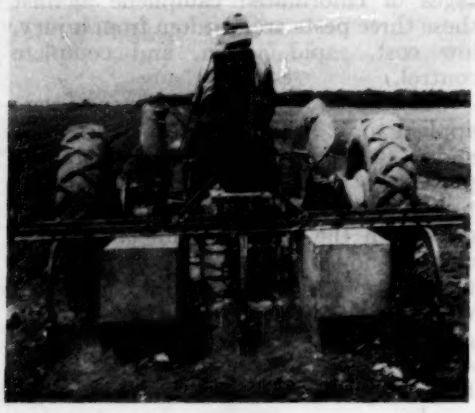

Fig. 1.—The dispenser (No. 1) designed for application of liquefied gas aerosols for control of the bean leaf beetle. (Experiments 1, 2 and 3.)

A heavy infestation of both bean leaf beetle and Mexican bean beetle appeared on the early planted string beans, and an extremely heavy infestation of Mexican bean beetle occurred on the lima beans.

The problems concerned with the successful control of these two insects fell into two categories: first, the design and construction of satisfactory dispensing equipment, and second, the formulation of effective insecticides (primarily extracts of derris and cube) in liquefied gas solutions, and the determination of minimum effective concentrations and rates of application.

Dispensing Equipment.—Because the equipment for applying liquefied gas aerosols is of simple construction and of light weight it appeared to the authors that there would be considerable advantage in attaching row crop dispensers to cultivators so that cultivation and insect control could be carried out in the same operation. It is hoped that such equipment will not only result in the saving of labor but also provide an incentive for growers to make more timely applications of insecticide.

During the season five dispensers to be attached to cultivators were designed and constructed, for tractor cultivators.[3,4]

The first dispenser (Fig. 1) consisted of two galvanized steel boxes fitted between the cultivator arms in such a manner as to cover the plants being cultivated. Each box or hood contained a single nozzle directed downward on the plants. This dispenser was highly efficient in treating young beans for the bean leaf beetle but because it was too small to allow proper nozzle adjustment for applying effective treatments against the Mexican bean beetle, larger dispensers were constructed.

Fig. 2.—The dispenser (No. 2) designed for application for liquefied gas aerosol for control of Mexican bean beetle.

A single large metal box or hood supported by an angle iron frame was bolted to the cultivator bars (Fig. 2); a bar across the top center of the box supported the nozzles in such a manner that any desired nozzle adjustment could be obtained. A

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[1] Scientific Article No. A-184. Contribution No. 2087 of the Maryland Agricultural Experiment Station (Dept. of Entomology).

[2] On the farms of A. O. Saulsbury and Bro., Ridgley, Md.

[3] The experiments reported in this paper were carried out with the Ford-Ferguson outfits. Another was constructed for an International "B."

[4] The name "cultisoler" is proposed for this type of dispenser.

dispenser of this type was satisfactory for treating both string and lima beans in all stages of growth. A fifth dispenser was constructed for use on cabbage and beans. All these dispensers were attached to the cultivators so that they could be lifted with the cultivator to avoid damage on turns at the end of rows.

On the outfits used in these tests the insecticide containers or tanks were carried in a rack supported by the cultivator bars and a valve on the feed line was placed so as to be accessible to the driver. The introduction of a pressure gauge in the line is not necessary but aids the operator in determining when the tanks are nearly empty. A filter in the feed line is necessary to remove iron oxide and other solid materials from the aerosol solution. On the cultivator dispensers a refrigeration filter[1] was found to be quite satisfactory. It contains a porous metal cone which will last 1 or more days depending on the amount of solid foreign matter in solutions. The metal cone is difficult to clean and once dirty is thrown away (replacements cost approximately 40 cents.) Felt and cloth filters should be avoided as small pieces of hair and fiber break away and cause nozzle stoppage.

FORMULATION OF AEROSOL SOLUTIONS.[2]—The problems confronted in compounding aerosol solutions for the Mexican bean beetle were (1) formulation of satisfactory aerosol solutions with derris and cube extracts so that line and nozzle stoppage should not occur, (2) determination of the toxicity of other insecticides applied in liquefied gas aerosol, primarily pyrethrum and synergists for pyrethrum or rotenone, and (3) the determination of minimum effective concentrations of toxicants in aerosol solutions and the minimum effective rate of application. Observations on the use of small amounts of carbon dioxide in formulation were also made. In general all formulations used in this work were based on the pea aphid formula (Ditman *et al.* 1947) which was composed of DDT, 5 per cent; solvent,[3] 10 per cent acetone, 35 per cent; and methyl chloride, 50 per cent. In compounding solutions for Mexican bean beetle acetone extracts of cube, derris, and pyrethrum were included at the expense of acetones. Small amounts of carbon dioxide were used as replacement for part of the methyl chloride propellant to increase the pressure. It is soluble in methyl chloride formulations and can be used only up to this amount.

EXPERIMENTS AND RESULTS.—The evaluation of the toxicity of insecticides used to control the Mexican bean beetle is not simple. Insecticides that show high toxicity in efficient laboratory applications may not show comparable lethal effect when applied in commercial field treatments. Pre- and post-treatment counts of adult beetles do not always indicate actual mortality under field conditions. When first affected by an insecticide the beetles take to wing so that dead beetles cannot be readily recovered. Often non-toxic materials will show varying degrees of repellency to adults, resulting in apparent control while beetles merely moved to untreated areas. Also after treatments, beetles migrate from heavily injured check plots to the better foliage of treated plots. Where adults are emerging from pupae on plants, a good kill of adults present at time of treatment might be obtained yet post-treatment counts would indicate poor results because of the presence of these newly emerged individuals.

In order to determine as accurately as possible the toxicity of the various formulations and insecticides used, counts of adults and estimates of larval populations were made before and after treatments. Treated adults were sometimes collected and caged for observation, and extensive searches for dead insects in fields, and examinations of the condition of plants from time of treatment till harvest, were made.

When control measures were directed against larvae, larval populations were estimated by the scoop method. A metal scoop 2 feet long and 12 inches wide is placed under one side of the row of vines, which are bent over the scoop with an inverted wooden "T." The wooden "T" is struck with another stick to dislodge larvae into the scoop for counting. This method was found to give a rapid index to insecticide efficiency. In this particular work scoop samples were not taken at random but at points where the beetle population was highest as indicated by greatest foliage injury.

The experiments reported here were

[1] *Wabash No. 090.*

[2] Mr. W. F. Barthel of the Victor Products Corp., Hagerstown, Maryland, prepared all solutions used in this work.

[3] *Velsicol AR-60.*

carried out on single plots, on isolated fields, in replicate plot arrangement, and in commercial acreages. All the liquefied gas aerosols were applied with the dispensers already described. The tractors were run at normal cultivating speed, *i.e.* full throttle in second speed, estimated at 6 m.p.h. Variation in dosage was obtained by changing size of nozzles.

Experiment 1. This experiment was conducted primarily to determine the effect of DDT aerosol against the bean leaf beetle, but inasmuch as a heavy migration of Mexican bean beetle adults occurred between the time of planning the experiment and the application of the insecticide, observations were made on both species. The first trilobed leaves were well developed at the time the aerosols were applied. Four DDT aerosol formulations were applied on May 27, with the No. 1 dispenser equipped with 2-gallon-per hour nozzles to single plots of approximately 4 acres each. The active insecticides in the formulation and results of population counts are given in table 1. Observations after treatment showed complete control of the bean leaf beetle on all treated plots and the check on the leeward side of the treated plots. There were dead leaf beetles present after treatment but there was no apparent mortality of the Mexican bean beetle. Observation at time of treatment indicated that all treatments caused Mexican bean beetles to become restless and that many of them took wing. Later examination of 7 acres on the windward side of the treated plots showed a heavy bean beetle population, 25 adults per 100 plants, an indication that treatments were somewhat repellent.

Beans receiving the 10 per cent DDT formulations showed what appeared to be growth stimulation, developing heavier and stronger vines than untreated areas. Growth stimulations were not demonstrated in subsequent experiments with 5 per cent DDT formulations.

Experiment 2. This was an exploratory test of a number of formulations applied with the No. 1 dispenser for control of both bean leaf beetle and the Mexican bean beetle. The various aerosols were applied to single plots varying from 0.25 acre to 8 acres in size. Population counts were not made on all plots but on samples at several points in the field and showed an average of 36 Mexican bean beetles and 19 bean leaf beetles per 100 plants.

Table 1.—Effect of some DDT aerosol formulations on control of the bean leaf beetle and Mexican bean beetle (Experiment 1) treatments applied May 27.

Formula No.	Per Cent DDT	Per Cent CO_2	Population Counts per 100 Plants			
			Bean Leaf Beetles		Mexican Bean Beetles	
			May 27	May 28	May 27	May 28
165	5	10	4.7	0	6.4	2.6
166	10	10	4.4	0	2.2	6.0
164	10	10	4.3	0	16.4	2.9
163	5	10	7.0	0	7.0	3.1
Check	—	—	5.5	0	3.3	3.1

In addition to plant counts, sprayed Mexican bean beetles were collected immediately after treatment and placed on untreated foliage while untreated beetles were placed on treated foliage from each plot. The nature of the treatments and the results on the Mexican bean beetle are given in table 2. With the exception of formula 1, only the heavier dosages of pyrethrum and the formulas containing rotenone appeared to kill the beetles which were hit by the spray though all beetles died when confined to foliage from all sprayed plots. Observations in the field, though revealing the presence of dead Mexican bean beetles, indicated that adequate coverage was not obtained with a single nozzle per row.

Because all the treatments gave complete control of the bean leaf beetle, detailed results are not given in table 2. Only two living beetles were found on all the plots and these were in a row near the check, having apparently moved into the area just before the results were taken.

Experiment 3. This was a single plot experiment with formulations containing rotenone with and without CO^2 at two

Table 2.—Exploratory tests on formulations of rotenone and pyrethrum on the control of the Mexican bean beetle (second experiment). Treatments applied May 29.

Formula No.	Per Cent Active Insecticide	Line Nozzles Gal. per Hr.	Beetles per 100 Plants May 30	Observations on Beetles: Sprayed Beetles on Clean Foliage	Observations on Beetles: Clean Beetles on Sprayed Foliage
170	DDT, 5; pyrethrum (20%) extract 3	2	3.8	feeding	down
170		4	12.0	down	down
176	DDT, 5; Dimethoxy DDT 5	2	9.8	on leaves	down
173	DDT, 5; pyrethrum (20%) extract, 2; piperonyl butoxide, 2	2	3.3	feeding	down
172	Dimethoxy DDT, 5; pyrethrum (20%) extract 2	2	5.8	feeding	down
1	DDT, 5; pyrethrum (20%) extract, 1[1]	2	6.6	down	down
171	DDT, 5; pyrethrum (20%) extract, 5	2	2.6	down	down
175	DDT, 5; Derris extract (37.2% rotenone), 2	2	4.0	down	down
174	DDT, 5; Derris extract (37.2% rotenone), 1	2	4.4	down	down
159	Derris resin 20% in acetone, 3.6; pyrethrum 20% extract, 2; DDT, 3%	2	9.3	some down	down
Check			16.3	feeding	few down

[1] Victor Products Corp. Household Aerosol Formula.

rates of application. These materials were applied June 3 with the No. 1 dispenser equipped with 2 and 4 gallon-per-hour nozzles to plots varying from 3 to 4.5 acres in size. Records were made only on Mexican bean beetles. Counts at several points in the field showed an average of 82 beetles per 100 plants. Nature of treatments and results are shown in table 3. There was a reduction of beetles and a considerable number of dead beetles were found in the field but none of the treatments gave what was considered satisfactory control.

Experiment 4. A 75 acre field was treated with 50 lbs. per acre of 0.75 per cent rotenone dust by aeroplane to determine the effectiveness of such treatment on Mexican bean beetles. Counts made at 10 row intervals from one edge of the field toward the center before treatment showed an average of 8.5 beetles per 100 plants. Forty-eight hours after treatment, counts in the same general area of the field showed an average of 8.0 beetles per 100 plants.

Experiment 5. In order to secure better plant coverage dispensers 2 and 3 were constructed. These dispensers (Fig. 3) were composed of simple large hoods sufficient to cover two rows with two nozzles per row. The nozzles were adjusted to spray each row from both sides. Four formulations were applied to single plots 2 to 4 acres in area on June 10, at which time bean plants were leafing out well but not yet in bloom. The nature of the treatments and results are given in table 4. At the time of treatments there were 27 egg masses per 100 plants, some of which were beginning to hatch. A considerable kill of beetles resulted from all treatments and though no larval counts

Table 3.—Effect of 2 rates of application with 3 rotenone aerosol formulations on Mexican bean beetle adults (Experiment 3).

Formula No.	Per Cent Active Insecticides	Per Cent CO_2	Size of Nozzle, Gallons per Hour	Bean Beetles per 100 Plants 12 Hours After Treatment
178	DDT, 5; Cube extract (20% resins) 10	5	4	25.0
178			2	18.5
179	DDT, 5; Cube extract (20% resins) 5	5	4	32.0
179			1	23.0
177		0	4	18.0
177	DDT, 5; Cube extract (20% resins) 5		2	39.0

were made, many dead young larvae were observed on the ground. Later observations did not show appreciable toxicity

FIG. 3.—The dispenser (No. 4) designed for treating large vined beans.

to egg masses nor was there any residual toxic effect apparent on larvae that hatched from them. With exception of the No. 1 check this entire field was treated again with formula 178 on June 23. Larval population indices by the scoop method showed 9 larvae per scoop in the plot receiving 2 applications of formula 178; 83 larvae in the untreated check plot; and 27 per scoop on the plot receiving 177 and 178. At harvest time the plot receiving two applications of 178 was in better condition than the other treated plot while the check had been totally destroyed.

Experiment 6. Two plots of approximately 5 acres in a 100 acre field of string beans were treated with the basic 5 per cent DDT formula to check the growth stimulating effect observed in Experiment 1. The beans were well up when the treatment was applied and observations throughout the growing period did not reveal any apparent differences in size or vigor of the treated and untreated plants.

Experiment 7. On June 19 a portion of the field treated by plane (Experiment 4) where the heaviest bean beetle infestation occurred was treated with formula 178 by dispensers 2 and 3. This area was about 20 acres in size and the plants were larger than any yet treated, being in full bloom. Larval population estimates by the scoop method 3 days after treatment showed 17.2 per scoop on the treated beans and 83.4 per scoop in an untreated check.

Experiment 8. On June 24, five formulations were applied with dispensers 2 and 3 to large-vined beans in which the young pods were beginning to show. There was an average of 35 larvae per scoop just before treatment and results taken 2 days after treatment are given in table 5. The kill secured on the large-vined beans was not satisfactory.

Experiment 9. It was apparent from results of experiments 5, 7, and 8 that two nozzles did not give adequate coverage of large bean plants. When plants were small high kills were obtained but as they increased in size the degree of control diminished. Dispenser 4 was then

Table 4.—Effect of rotenone aerosol formulations with and without CO_2 on bean beetles (Experiment 5) applied with dispenser 2 (2 nozzles per row).

Formula No.	Per Cent Active Insecticides	Per Cent CO_2	Size of Nozzle, Gallons per Hour	Mexican Bean Beetles per 100 Plants	
				June 10	June 11
178	DDT, 5; Cube extract (20% resins), 10	5	2	33.3	1.8
Check No. 1				31.0	12.7
174	DDT, 5; Cube extract (20% resins) 5	0	2	27.5	4.7
Check No. 2				36.0	41.1
177	DDT, 5; Cube extract (20% resins) 10	0	2	36.5	5.8

Table 5.—Effect of rotenone aerosols from derris and cube sources on Mexican bean beetle larvae (Experiment 7).

Formula No.	Per Cent Active Insecticide	Per Cent CO_2	Average Larvae per Scoop 2 Days After Treatment
178	DDT, 5; Cube extract (20% rotenone) 10	5	20.3
174	DDT, 5; Cube extract (20% rotenone) 5	0	21.7
180	DDT, 5; Derris extract (36.6% rotenone) 10	5	22.3
182	DDT, 5; Derris extract (25% rotenone) 10	5	35.2
181	DDT, 5; Derris extract (25% rotenone) 5	5	41.8

constructed. This dispenser was slightly wider than Nos. 2 and 3 and was equipped with 4 nozzles per row, a pair 5 inches apart on each side. On July 2, three aerosol formulations and two water sprays containing cube extract emulsion were applied to single plots of nearly mature string beans. Approximately 100 gallons of water spray and 25 to 30 pounds of aerosol solution were applied per acre. The dispenser was equipped with 3-gallon-per-hour nozzles. The nature of the treatments and the results are given in table 6. The results secured indicated that this heavy dosage of aerosol was equal or, to better than, the water spray.

Table 6.—Comparison of pyrethrum and rotenone aerosols with rotenone sprays on Mexican bean beetle larvae (Experiment 9).

Formula No.	Per Cent Active Insecticide	Per Cent CO_2	Bean Beetle Larvae per Scoop	
			July 2	July 4
Spray	1 part 5% rotenone emulsion to 400 parts water		65.4	10.7
189	Rotenone (derris) resin, 0.5; pyrethrins 0.4; piperonyl butoxide, 2	5	61.2	3.7
Spray	1 part 5% rotenone emulsion to 200 parts water		76.2	6.6
188	Rotenone (derris) resin, 0.5, pyrethrins, 0.4; N-propyl Isomer, 2	5	44.4	3.0
186	Rotenone (derris) resin, 2.0	5	45.8	7.6

The work was concluded on string beans with observations on the commercial treatment by the grower of three fields totaling 180 acres. Only edges or borders of the fields where the heaviest infestations were present were treated with formula 178. Dispensers 2 and 3 were used on the smaller beans and No. 4 was used on the larger vines. Observations preceding and following treatments showed that particularly good results were obtained where plants were small and adults had not begun to lay. In one field the bean beetle infestation was completely eliminated. Where larvae and eggs were present and the vines larger, results were not as good.

Experiment 10. The spring crop of string beans was followed by a fall crop of Henderson bush limas. Three 40 acre fields of this planting were infested to a degree that control measures were necessary. Field "A" was treated with dispenser 4 equipped with 2-gallon-per-hour nozzles using .5 and 1.0 per cent rotenone, 5 per cent CO^2 formulas. The plants in this field were comparatively large and in the early bloom stage when the first treatment was made. Treatments were applied on August 14 and 15 at which time larvae populations averaged 18.7 per scoop. On August 18, the part of the field treated with 0.5 per cent rotenone averaged 10.1 larvae per scoop while the plot treated with 1.0 per cent rotenone formula averaged 3.4. A careful check showed that 15 pounds of aerosol solution was applied per acre.

Subsequent observation of this field indicated that further treatment was necessary and on August 25 spot treatment of the heaviest infested area was made with the 0.5 per cent rotenone formula. The crop of beans secured from this field was equal to that from fields where treatments had not been necessary.

Fields B and C, each of 40 acres, were treated with dispensers 2 and 3 using 0.5 and 1.0 per cent rotenone formulas. These plants were small with only the first fully developed trifoliate leaves and the beetle was present in all stages on the plant. A careful check showed that exactly 10 pounds of aerosol solution was applied per acre. Before treatment there was an average of 25.8 larvae per scoop; 3 days later field B had 4.2 on the 0.5 per cent rotenone formula, 6.5 on the 1.0 per cent rotenone plot; field C had 6.0 larvae on the 0.5 per cent rotenone plot; 13.2 on the 1.0 per cent rotenone. The kill of larvae secured was satisfactory and there was apparently a good kill of adults. There was no toxicity to eggs observed and pupae were not killed. By August 25, so many young adults had emerged that a small portion of the field was treated with dispenser 4. Just before the second application was applied there were 5.5 adults and 5.7 larvae per scoop; 2 days after

treatment there were 2.0 adults and 6.3 larvae per scoop. Subsequent observation did not reveal any difference in appearance of the leaves receiving one and those receiving two treatments. An average crop of beans was secured from these fields, which without treatment would have been completely destroyed by the beetle.

Experiment 11. This final experiment was planned to determine the effect of varying concentrations of rotenone in aerosol solutions on the resulting yield of shelled lima beans. The following treatments were replicated four times in randomized blocks: (1) DDT 5 per cent aerosol applied early plus 2 later applications of 0.5 per cent rotenone in addition to 5 per cent DDT aerosol; (2) 2 applications of 0.5 per cent rotenone and 5 per cent DDT aerosol; (3) 2 applications of 1.0 per cent rotenone aerosol, and (4) 2.0 per cent rotenone aerosol. With exception of the 5 per cent DDT aerosol applied in treatment 1 to the beans just after they were up, all other applications were made on August 14 and August 25 with the number 4 dispenser. This dispenser was equipped with 1.65-gallon-per-hour nozzles for the August 4 treatment and 2-gallon-per-hour nozzles for the last applications. Results were based on the yield of shelled beans.

Observations at harvest time showed better foliage protection from the higher rotenone applications but this difference was not reflected in crop yields. The early application of DDT aerosol did not show the beneficial effect that occurred in experiment 1. The plots receiving the No. 1 treatment averaged 56.8 lbs. of shelled beans per plot; the No. 2 treatment averaged 60.2 lbs.; and the No. 4 treatment 59.5 lbs. Two sets of untreated check plots averaged 46.5 and 40.0 lbs. of shelled beans.

DISCUSSION AND SUMMARY.—The dispenser used proved, under field conditions, and when operated by farm labor, to be a practical, efficient, and durable apparatus for applying insecticide. This dispenser is simple and inexpensive to construct and because of its light weight, easy to handle. It provides uniform applications of insecticide to plants since cultivating must be done with considerable accuracy.

None of the difficulty was experienced with nozzle and line stoppage that had developed with formulations used in earlier work (Ditman *et al.* 1946). This may have been eliminated by the substitution of the commercial solvent[1] for the lubricating oil of early formulas and by the practice of allowing acetone-rotenone extracts to settle at least 24 hours before using. The introduction of satisfactory filters in the feed line eliminated iron rust and other solid matter in aerosol solutions.

All insecticides used were highly effective against the bean leaf beetle but only the formulations with a comparatively high pyrethrum content or those containin rotenone were effective against Mexican bean beetle larvae and adults. These results verified the findings of Ditman & McConnell (1940)[2] in which a high degree of control was secured with concentrated pyrethrum-water sprays. Pyrethrum at a constant rate per acre was highly effective when applied in 10 gallons of water per acre but when applied at 150 gallons per acre it was not effective. Pyrethrum and rotenone-containing aerosols applied by Ditman *et al.* (1946) gave excellent results against the bean beetle but considerable trouble was experienced with nozzle and line stoppage at that time. The dimethoxy analog of DDT and the two synergists N-propyl isomer and piperonyl butoxide in aerosol application were of little value in control of the bean beetle as indicated by results repeated here. In 1946 (Ditman *et al.*) a water emulsion of the dimethoxy analog of DDT did not give kills of bean beetle comparable to rotenone spray and aerosols and pyrethrum aerosol.

The degree of control secured with both pyrethrum and rotenone aerosols varied with the coverage secured in the application. This was particularly apparent when treating heavy larval populations. Where the plants were small excellent results were obtained, but as the plants grew and the bean beetle was present in all stages of development the degree of control diminished. It appears from data secured and from frequent observations of fields treated in all stages of growth that successful treatments for this insect are those applied early so as to reduce or eliminate the adult beetle population before egg laying has occurred. None of the insecticides used either in water sprays or aerosols showed any appreciable effect on

[1] *Velsicol AR-60.*
[2] Unpublished data. Maryland Agr. Expt. Sta. Reports.

eggs or pupae. Larvae molting just after treatment appeared also to survive.

From the standpoint of cost and effectiveness, formula 178 appeared to be most practical. The effectiveness of the aerosol application was only slightly increased by doubling the amount of rotenone in the formulation and increased the cost for 10-pound-per acre applications about $1.00. Formula 178 was applied at a 10 pound per acre rate at approximately $4.00. The cost of pyrethrum formulations was higher.

Methyl chloride proved to be a satisfactory propellant and was used in nearly all formulations in Maryland in 1947, both in experimental work and for commercial treatments of peas and beans. No deleterious effects were experienced by the operators of dispensers or field men. The addition of CO_2 to formulations is of questionable value. The CO_2 increases the solution pressure and increases the rate of application for any given size nozzle and until similar formulas with and without CO_2 are compared at the same rate of application conclusions cannot be drawn.

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Chlorinated Camphene on Potatoes[1]

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Preliminary tests in 1945,[3] in which chlorinated camphene[4] was applied to Irish Cobbler potatoes, gave leafhopper-control *Empoasca fabae* (Harr.), equal to that obtained with DDT at the same rate. During 1946, more extensive tests were conducted with both early and late potatoes. Leafhoppers were not abundant on either planting and their control did not affect the yield.

FLEA BEETLE CONTROL.—In 1947, chlorinated camphene and DDT were compared, alone and in combination with zinc dimethyldithiocarbamate,[5] zinc ethylene bis (dithiocarbamate[6]), and copper oxychloride,[7] on Irish Cobbler potatoes for compatibility and effectiveness in the control of potato insects. Leafhopper, aphid, and Colorado potato beetle infestations failed to develop. However, the flea beetle, *Epitrix cucumeris* (Harr.), was abundant, and was the principal insect against which these insecticides were applied.

Thirteen treatments were replicated three times on five-row plots, with the rows 42 inches apart and 50 feet long.

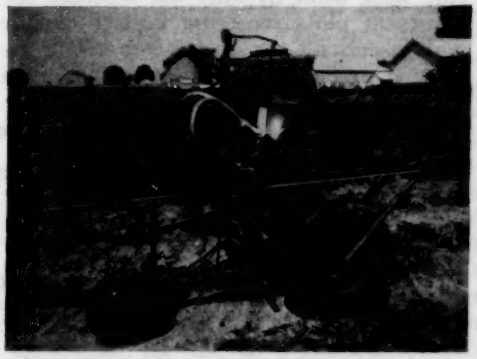

FIG. 1.—Side view of self-propelled, power sprayer-duster.

The plots were randomized in four blocks with 5-foot alleys separating the blocks. Six spray applications were applied on May 27, June 5, 10, and 25, and July 2 and 16 under 200 pounds' pressure with a power sprayer (Figs. 1 and 2). The amount of spray used was gradually increased in line with the plant growth. Expressed on an acre basis, it ranged from 75

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[2] Hercules Research Fellow, Entomology; Temporary Assistant Entomologist; and Research Professor, Entomology, respectively.

[3] In cooperation with J. W. Heuberger, then Associate Research Professor, Plant Pathology, University of Delaware.

[4] *Toxaphene*, trade mark of Hercules Powder Company.

[5] *Zerlate.*

[6] *Dithane Z78.*

[7] *Copper A Compound.*

gallons in the first application to 200 gallons in the last application.

FIG. 2.—Self-propelled, power sprayer-duster operating as sprayer.

Insect counts were made prior to the first application and 24 hours after each succeeding application. No difference could be detected in the size, color, or development of the plants under the various treatments during the early part of the growing season. However, a marked difference was recorded subsequently in flea beetle-population, especially in the case of treatments not containing an insecticide. As a result, untreated plants and all plants in plots receiving only a fungicide were dead by July 22, whereas the plants in plots receiving both fungicide and insecticide or insecticide alone remained green and were partially green when dug on August 5. A very late, early blight, *Alternaria solani* (Ell. & Mart.) J. & G., infection did not affect the yields. Differences can, therefore, be ascribed wholly to the control of the potato flea beetle.

The three center rows of each plot served as record rows; thus, four buffer rows separated the record rows of each plot. The crop was hand-graded into two grades—marketable potatoes (U. S. No. 1 and No. 2, combined) and culls.

Plots receiving the chlorinated camphene water miscible treatment produced the highest yield; 463 bushels per acre. Yields of other treatments were in the following order: DDT plus copper oxychloride (460 bu. per acre); DDT water miscible (425 bu. per acre); chlorinated camphene plus copper oxychloride (419 bu. per acre); DDT plus fungicide[1] and chlorinated camphene plus fungicide[1] (398 and 384 bu. per acre, respectively); chlorinated camphene (25 per cent wettable powder (369 bu. per acre); DDT plus fungicide[2] (359 bu. per acre), chlorinated camphene plus fungicide[2] (322 bu. per acre); fungicide[1] alone (307 bu. per acre); untreated (297 bu. per acre); copper oxychloride (292 bu. per acre) and, lastly, fungicide[2] alone (266 bu. per acre). These yield data are included in table 1.

[1] *Dithane.*
[2] *Zerlate.*

Table 1.—Potato flea beetle and yield data, for chlorinated camphene and DDT treatments, Delaware, 1947.

Treatments	Rates per 100 Gallons of Water	Average Number of Flea Beetles per Leaf	Yield in Bushels per Acre	
			Marketable Potatoes[1]	Culls
Chlorinated camphene 32% water miscible[2]	1.3 quarts	0.47	463	58
DDT 32% water miscible[3]	1.3 quarts	0.09	425	81
Chlorinated camphene 25% wettable powder[2]	4 pounds	0.32	369	42
Chlorinated camphene 32% WM+fungicide[4]	1.3 qts.+2 lbs.	0.47	322	54
DDT 32% WM+fungicide[4]	1.3 qts.+2 lbs.	0.24	359	44
Fungicide[4] alone	2 pounds	3.55	266	50
Chlorinated camphene 32% WM[2]+fungicide[5]	1.3 qts.+2 lbs.	0.19	384	48
DDT 32% WM+fungicide[5]	1.3 qts.+2 lbs.	0.19	398	44
Fungicide[5] alone	2 pounds	3.73	307	42
Chlorinated camphene 32% WM+Compound A	1.3 qts.+3.3 lbs.	0.16	419	44
DDT 32% WM+Compound A	1.3 qts.+3.3 lbs.	0.32	460	37
Compound A	3.3 pounds	3.44	292	31
Untreated check		6.29	297	37

[1] U. S. Grades Number 1 and 2, combined; difference of 38 bushels required for significance at 5% point.
[2] Toxaphene 32%, Velsicol AR-60 65%, and Triton X-100 3% by weight formulation.
[3] DDT 32%, Velsicol AR-60 65%, and Triton X-100 3% by weight formulation.
[4] *Zerlate.*
[5] *Dithane Z78.*

Table 2.—Comparative phytotoxicity, chlorinated camphene and DDT formulations on potatoes, Delaware, 1947.

TREATMENTS	VISIBLE RESIDUE	RATES OF TOXICANT PER 100 GALLONS OF WATER			
		0.5 lb.	1 lb.	2 lbs.	4 lbs.
Chlorinated camphene 25% wettable powder	Heavy	Safe	Safe	Safe	Chlorosis
DDT 50-W	Heavy	Safe	Safe	Safe	Safe
Chlorinated camphene 32% water miscible	None	Safe	Safe	Bronzing	Necrosis
DDT 32% water miscible	None	Safe	Safe	Bronzing	Necrosis
Chlorinated camphene 50% water dispersible	None	Safe	Safe	Safe	Safe
DDT 25% water dispersible	None	Safe	Safe	Safe	Safe
Solvent and emulsifier[1]	None	Safe	Safe	Safe	Safe
Untreated check		No Injury			

[1] Solvent and emulsifier of the water dispersible formulation (*Shell E-407* and *Tween G-1045*).

Phytotoxicity.—Irish Cobbler potato plants were transplanted from the field into eight-inch clay pots. After allowing 1 week for them to become adjusted, they were sprayed on June 1 with a knapsack sprayer. Chlorinated camphene and DDT were applied at 0.5, 1, 2, and 4 pounds per 100 gallons of water. On June 5, the first evidence of toxicity appeared on plants treated with the 2-pound concentration of both the chlorinated camphene and DDT water miscible formulations; and on June 12, the effect was noted as bronzed areas along the veins of the leaflets. At the 4-pound rate, a similar condition resulted, accompanied with marginal burning of the leaflets. Since both the chlorinated camphene and DDT formulations produced identical symptoms, the injury was probably due to the solvent.[1]

By June 12, chlorinated camphene 25 per cent wettable powder at 16 pounds per 100 gallons of water had produced chlorosis which was followed by a mottling of the potato leaves. No injury was apparent from the use of DDT 50W[2] at any of the concentrations tested. Treatments and phytotoxicity data appear in table 2.

SUMMARY.—In field tests with potatoes, prior to 1947, chlorinated camphene gave a control of the potato leaf hopper, *Empoasca fabae* (Harr.), equal to that obtained with DDT used at the same rate. During 1947, 13 treatments, including chlorinated camphene and DDT alone and in combination with fungicides[3] and copper oxychloride, were applied to early potatoes. Chlorinated camphene like DDT, proved to be compatible with these three fungicides, and gave approximately equal control of the potato flea beetle, *Epitrix cucumeris* (Harr.).

No fungicidal treatment by itself showed a yield significantly greater than the untreated control. Yields of marketable potatoes were increased, however, by the use of an insecticide with a fungicide. All combinations containing either chlorinated camphene or DDT, water-miscible chlorinated camphene plus a fungicide[4] excepted, produced yields significantly greater than those obtained with the fungicides in question. Although the difference in yield between the chlorinated camphene 32 per cent water miscible and the DDT 32 per cent water miscible treatments is exactly that required for significance at the 5 per cent point, this difference was not significant at the 1 per cent point. All other chlorinated camphene treated-plots ranged slightly below those receiving similar DDT treatments, although not significantly so at the 5 per cent or 1 per cent levels. The yield, in the case of the chlorinated camphene 32 per cent water miscible plots, was significantly greater than that for the 25 per cent wettable powder plots.

Results of phytotoxicity tests indicate that chlorinated camphene 25 per cent wettable powder and the 32 per cent water miscible and 50 per cent water dispersible formulations of this compound are safe on potatoes at the concentration of 1 pound per 100 gallons of water.

[1] *Velsicol AR-60.*
[2] Dupont's *Deenate 50-W.*
[3] *Zerlate* and *Dithane 278.*
[4] *Zerlate.*

Pea Aphid Control Experiments in Virginia in 1947

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In view of the good control of pea aphid *Macrosiphum pisi* (Kalt.), obtained with some of the new insecticide mixtures in experiments last season, it seemed advisable to continue these tests again this year.

Due to a late cool spring the pea aphids began appearing in abundance on alfalfa and other legumes about 2 weeks behind the normal season, and migration to peas occurred during the first week of May, which was later than usual. By the end of the first week in May the population averaged from 50 to 60 aphids per sweep of a 15 inch diameter net. By the middle of May the population was up to about 400 per sweep, at which point it leveled off for a few days before beginning a decline. By May 25 the population had dropped to an average of 100 per sweep. All insecticide applications were made between May 6 and 14 at which time the aphids were unusually free of parasites and disease and were in a very active condition.

TEST EQUIPMENT.—Dust materials were applied with a motor-driven eight-nozzle tractor-drawn duster, equipped with a 35-foot cloth canopy trailing the machine, and an airplane[1] crop duster. Spray materials were applied with an orchard sprayer equipped with a single pipe boom with 10 nozzles, and a biplane equipped with a special spray boom across the lower wing. Aerosols were applied with an experimental machine equipped with 12 oil burner nozzles. All of this equipment except the biplane sprayer has been described in detail in an earlier publication (Anderson & Brooks 1947). The only changes made in the equipment are that the apron was left off of the aerosol machine and an 8 inch sheet metal curtain was attached on all sides of the frame. All ground equipment was pulled by tractor and was adjusted to cover 10-foot swaths of broadcast peas. Air equipment covered from 30 to 50-foot swaths.

METHODS OF TAKING RECORDS.—Aphid populations were determined by making 10 sweeps with a 15-inch diameter insect net in each plat. In all tests counts were made 3 days and again at 6 to 7 days after treatment. In two experiments a third count was made, one at 12 days and the other at 18 days after treatment. Samples of less than 100 aphids were usually counted in the net in the field. Larger samples were put in paper bags, killed and dried by heat treatment, and counted within a few days after collection.

Yield records were taken in the Onley experiment by harvesting 200 plants from each replicate of two treatments and from the untreated check plats. These plant samples harvested for yield records were also used for residue analysis. All data was analyzed by Fisher's method for analysis of variance.

ONLEY EXPERIMENTS.—The field used for the test at Onley was a uniform broadcast planting of Alaska peas. At the time of treatment on May 6, the plants were about a foot tall and had not bloomed. All plats were 180 feet long and 10 feet wide, with a 2-foot alley between plats. Each treatment was replicated four times in randomized blocks. Aerosol treatments were made between 5:00 and 6:00 P.M. during which time the temperature dropped from 70° to 60° F., the relative humidity went up from 55 to 85 per cent and the wind velocity ranged from 3 to 5 miles per hour. Dust treatments were made from 6:00 to 8:00 P.M. and the temperature dropped from 60° to 54° F. with the relative humidity staying at about 85 per cent. The wind velocity was 2 miles per hour for the first few minutes and a dead calm during the rest of the time when the dusts were being applied. Treatments were made under exceptionally favorable weather conditions and a dust cloud hung over the vines for several minutes after each treatment.

The different materials tested, rate of application and the results obtained are given in table 1. All treatments resulted in highly significant reductions in aphid populations. Yield records taken on two of the treated areas showed a significant increase over the yield of the untreated area. Due to the fact than an almost perfect kill was obtained with all treatments it is difficult to show any differences between

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[1] Piper Cub.

treatments. The counts show the 5 per cent DDT aerosol using methyl chloride as the propellent to be inferior to the 8 per cent DDT aerosol using carbon dioxide as the main propellent, as well as inferior to practically all other treatments. Except for the 2 per cent DDT+2 per cent conditioner[1] and the 0.5 per cent gamma isomer of benzene hexachloride dusts, the 2 per cent regular DDT material was inferior to all the other DDT and benzene hexachloride dusts in the 7-day counts. foliage from the plants on which yield records were taken showed no DDT on the untreated check plants. The 1 per cent DDT+2 per cent conditioner[2] dusted area analyzed 0.32 parts per million dry weight, while the aerosol treated plants had 40 parts per million dry weight. Plant samples for analysis were taken 21 days after treatment, during which time four light showers of rain had fallen for a total of 0.48 inch of rain. No disagreeable odor was observed on the peas or

Table 1.—Results of treating broadcast Alaska peas for the control of pea aphids at Onley, Virginia. Treated May 6, harvested May 27, 1947.

Materials Used[1]	Particle Size Microns[2]	Lbs. per Acre of Insecticide	Average No. Aphids per Sweep After Treatment		Yield Lbs. Shelled Peas per Acre
			3 Days	7 Days	
2% DDT	25	54	2.2	12.2	
2% DDT+2% solvent[3]	25	46	1.5	8.1	
1% DDT+2% solvent[3]	25	51	1.1	5.8	
1% DDT+2% solvent[3]	5	48	0.6	4.0	
1% DDT−2% solvent[4]	?	42	1.2	5.8	970
1% DDT−2% non-volatile solvent[4]	?	36	1.8	6.3	
Benzene hexachloride (1% gamma)	5	45	2.8	9.0	
Benzene hexachloride (0.5% gamma)	60	57	1.8	6.5	
Benzene hexachloride (1% gamma)	60	46	1.3	4.5	
Benzene hexachloride (1% gamma)	?	50	0.9	2.7	
Benzene hexachloride (1% gamma)	?	48	1.5	4.4	
8% DDT aerosol[5]	—	10	1.7	4.2	1002
5% DDT aerosol[6]	—	10	4.5	15.3	
Untreated check	—	—	57.8	250.6	600
Difference required for significance (19 to 1 odds)			1.87	4.9	340

[1] Pyrophyllite is the diluent used in all dusts.
[2] Particle size determined by microscopic examination of DDT and benzene hexachloride concentrates before diluting.
[3] *Velsicol AR 60*, added at the end of the mixing process.
[4] The DDT was dissolved in the solvent before mixing with the diluent.
[5] U.S.D.A. Formula #123. 8% DDT-8% cyclohexanone-8% *Velsicol AR 60*-56% acetone-8% methyl chloride-12% carbon dioxide.
[6] U.S.D.A. Formula #65. 5% DDT-5% cyclohexanone-5% *Velsicol AR 60*-35% acetone-50% methyl chloride.

The slightly poorer performance of the 2 per cent DDT+2 per cent conditioner[2] dust may be accounted for by the fact that in this test this material did not flow uniformly from the duster and a splotchy coverage was obtained on the plants. Good coverage seemed to be obtained with all other treatments. There appeared to be little differences in the aphid control with DDT and benzene hexachloride dusts in which the particle size of the active ingredient ranged from 5 to 60 microns diamter in the concentrate before dilution. DDT particles were not discernible with a microscope after the conditioner[1] was added to the mixture. Analysis of the vines from the benzene hexachloride treated plats at harvest time, nor in the peas when cooked and eaten by over 20 different people.

MACHIPONGO EXPERIMENTS.—The field selected for this test was a uniform broadcast planting of super Alaska peas. At the time of treatment the plants were in full bloom. The plats were 10 feet wide and approximately 200 feet long and each treatment was replicated three times. Treatments were made on May 11, between 4:30 and 6:45 P.M. during which time the temperature dropped from 57° to 49° F. and the relative humidity went from 53 to 60 per cent. The wind velocity varied from 5 to zero miles per hour.

The different materials tested, rates of

[1] *Velsicol AR-60.*

application and results obtained are given in table 2. These records show that all treatments gave a highly significant reduction in the aphid population. The 18-day counts show the same trends in aphid populations as the 3 and 6-day counts, but the differences are not as great, due to the fact that the plants were nearing maturity

EXMORE EXPERIMENT.—This test was run on a uniform broadcast planting of Thomas Laxton peas that were about through blooming. The plats were 10 feet wide and 180 feet long and replicated four times. Treatments were made on May 14, between 5:30 and 6:30 P.M. The temperature was 70° F., the relative

Table 2.—Results of treating broadcast super Alaska peas for the control of pea aphids at Machipongo, Virginia. Treated May 8, 1947.

MATERIALS USED	AMOUNT PER ACRE	AVERAGE NO. APHIDS PER SWEEP AND % CONTROL OVER CHECK AFTER TREATMENT				
		3 Days		6 Days		18 Days
Dusts[1]	Lbs.	No.	%	No.	%	No.
2% DDT	52	4.2	94	42.2	91	60.7
2% DDT+2% solvent[2]	51	2.9	96	15.5	97	24.6
1% DDT−2% solvent[2]	46	4.7	93	27.3	94	43.3
0.5% DDT−2% non-volatile solvent[2]	49	5.1	92	39.3	91	55.9
0.5% DDT−2% non-volatile solvent[2]−0.06% pyrethrins[2]	51	3.1	95	26.3	94	36.1
Benzene hexachloride (1% gamma)	56	4.6	93	7.0	98	29.7
0.25% parathion	52	13.6	79	107.0	76	73.3[3]
1% Rotenone−3% conditioner[2]	24	24.1	63	206.5	54	81.6[3]
Sprays	Gallons					
DDT 25% emulsion (1 qt.–100 gallons water)	147	3.5	95	12.0	97	45.3
Hexaethyl tetraphosphate (pure) 1 pt.–100 gallons water)	140	11.2	83	84.6	81	72.7[3]
8% Piperonyl cyclohexanone-0.8% pyrethrins emulsion (1 qt.–100 gallons water)	133	13.9	79	124.7	72	59.7[3]
Untreated check	—	65.4	—	446.0	—	132.0[3]
Difference required for significance (19 to 1 odds)		4.5		38.4		20.4

[1] Pyrophyllite is the diluent used in all dusts except the benzene hexachloride which was diluted with pyrophyllite and clay.
[2] *Velsicol AR-60;* the DDT was dissolved in the solvent before mixing with the diluent.
[3] Population decreasing due to maturity of plants.

and on the plats where poor aphid control had been obtained the population had leveled off and decreased since the 6-day count. The rotenone dust apparently contained too much oil and did not dust well, and as a result only half of the desired amount was applied. This may account for this material giving significantly poorer control than any of the other treatments. The piperonyl cyclohexanone-pyrethrum spray and the parathion dust with an average of from 75 to 77 per cent kill and the hexaethyl tetraphosphate with 82 per cent kill in the 3 and 6-day counts, were significantly better than the rotenone treatment but significantly poorer than all other treatments. All of the DDT sprays and dusts and the benzene hexachloride dusts gave from 91 to 98 per cent control with no significant differences between any of them.

humidity 77 per cent and the wind velocity ranged between 0.75 to zero miles per hour. Within a half hour after treatment time the temperature dropped rapidly to 55° F. accompanied by a brisk wind. The materials tested, rates of application and the results obtained are given in table 3. As may be seen by these records, all treatments gave highly significant decreases in aphid populations in the 3 and 6-day counts. In this test as in the Onley test there seemed to be little difference in the control obtained with DDT dusts of different particle size. The 2 per cent DDT dust without oil gave 85 to 82 per cent control which was significantly poorer than all other DDT and benzene hexachloride treatments, all of which gave over 95 per cent control. The 12-day counts agree very closely to the other counts except for the counts on the untreated checks

which had declined about 75 per cent from the 6-day count due to the aphid injury and subsequent early maturity of these plants.

AIRPLANE TESTS.—On May 10, several different insecticides were applied with airplane equipment. Weather conditions were favorable and good coverage was obtained. The plats were from 2 to 3 acres in size. The concentrated spray materials applied with a biplane were: DDT, 0.33 gallon per acre (1 pound actual DDT per acre), benzene hexachloride, 3 gallons per acre (0.3 pound gamma isomer per acre) and hexaethyl tetraphosphate, 3 gallons per acre (1 pound pure hexaethyl tetraphosphate per acre). Aphid counts made on May 14 showed 420 to 550 aphids per sweep of the net with no significant differences between treatments. The untreated check area which was on the far side of the field had 450 aphids per sweep. The benzene hexachloride treatment severely injured the foliage. The rest of the field, which was over 100 acres in size, was treated the same day with a 1 per cent DDT—2 per cent oil dust at the rate of 50 pounds per acre applied by a Piper Cub crop duster. The aphid population on this treated area on May 14 was 50 aphids per sweep.

Dust and spray applications on Shasta peas made by airplane equipment were compared again on May 23. The same type of equipment as was used in the May 10 test was used in these tests but they were owned and operated by a different company. Materials were applied under favorable weather conditions. The aphid population was not as thriving or as large as in the previous test and a considerable amount of fungous disease was present among the aphids. A concentrated DDT spray was applied at the rate of 5 gallons per acre (1 pound actual DDT per acre) in comparison with a 1 per cent rotenone—20 per cent sulphur dust at 40 to 50 pounds per acre. Counts made on May 27 showed 20 aphids per sweep where the DDT spray was used, 60 per sweep where the rotenone was used and 200 in the untreated area. Another neighboring field treated the next day by the same airplane spray equipment using the DDT concentrate, but without any ground crew to check on operations, showed 44 aphids per sweep as compared to 100 per sweep on the untreated area.

Table 3.—Results of treating broadcast Thomas Laxton peas for the control of pea aphids at Exmore, Virginia. Treated May 14, 1947.

Material Used[1]	Particle Size Microns[2]	Lbs. per Acre of Insecticide	Average No. Aphids per Sweep and % Control Over Check After Treatment				
			3 Days		6 Days		12 Days
			No.	%	No.	%	No.
2% DDT	25	41	62.6	85	71.5	82	41.7
2% DDT+2% solvent[3]	25	38	16.7	96	21.1	95	18.9
1% DDT+2% solvent[3]	25	45	19.0	95	18.9	95	27.4
1% DDT+2% solvent[3]	5	41	17.6	96	20.3	95	20.2
Benzene hexachloride (1% gamma)	?	38	14.2	97	16.9	96	17.7
Untreated check	—	—	407.0	—	405.0	—	97.9[4]
Difference required for significance (19 to 1 odds)			14.1	—	21.0	—	11.1

[1] Pyrophyllite is the diluent used in all dusts except the benzene hexachloride which was diluted with clay and pyrophyllite.
[2] Particle size determined by microscopic examination of DDT and benzene hexachloride concentrates before diluting.
[3] The solvent, *Velsicol AR 60* was added to the DDT dusts at the end of the mixing process.
[4] Population decreasing due to maturity of the plants.

AEROSOL EXPERIMENTS.—In addition to the aerosol tests made in the Onley experiment three other field size experiments were made with the same equipment testing several different formulations. These tests were made in cooperation with the United States Department of Agriculture, Bureau of Entomology and Plant Quarantine and are being reported in detail in a separate paper (Smith *et al.*). Only a summary of the results will be given here. In general it may be said that 5 to 8 per cent DDT aerosols using methyl chloride or carbon dioxide as the main propellent gave equal aphid control which was approximately 94 per cent. Aerosols containing 5 per cent gamma isomer of benzene hexachloride also gave 94 per cent

control while the 2.5 per cent gamma isomer material dropped to 89 per cent. Ten per cent hexaethyl tetraphosphate in oil gave 90 per cent control and without oil 83 per cent control while 5 per cent chlordane and 5 per cent chlorinated camphene dropped to 72 and 68 per cent control respectively. The benzene hexachloride and the hexaethyl tetraphosphate were disagreeable to handle and the benzene hexachloride caused some foliage injury.

SUMMARY.—Good pea aphid control was obtained with 0.5, 1 and 2 per cent DDT—oil dusts in which the DDT was dissolved in the oil then mixed with diluent or in which the oil was added after the diluent. Two per cent DDT dust without oil was less effective than the DDT dusts with oil. DDT—oil emulsion spray was equal to the DDT dusts when applied by ground equipment while DDT aerosols were equal to or slightly less effective than the DDT dusts.

Benzene hexachloride dusts containing 0.5 to 1 per cent gamma isomer gave good aphid control. Benzene hexachloride and DDT dusts from several different sources were equally effective. Particle sizes of 5 to 60 microns for the DDT and benzene hexachloride concentrates had little effect on the toxicity of the finished dusts.

One per cent rotenone, 0.25 per cent parathion dusts, hexaethyl tetraphosphate and piperonyl cyclohexanonepyrethrum sprays gave poor aphid control.

Airplane applications of DDT dust less the oil gave good control. In one test airplane applications of DDT spray gave good control while in another test DDT, benzene hexachloride and hexaethyl tetraphosphate sprays gave no control.

In the aerosol form, DDT and benzene hexachloride gave good control and hexaethyl tetraphosphate fair control while chlordan and chlorinated camphene gave poor control.

Some foliage injury occurred when benzene hexachloride was used as a spray or aerosol. Also benzene hexachloride and hexaethyl tetraphosphate were disagreeable to handle. Although benzene hexachloride imparted no odor or taste to the peas at harvest time, further investigation is necessary before this material can be recommended for use on peas.

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Compatibility of DDT with Commercial Limes

ROGER W. ROTH[1]

Copper lime dusts used for the control of late blight are very reliable and there is still a lot of interest in their use for combating the disease. However, the combination of hydrated lime and DDT is considered incompatible. Therefore, the use of copper lime dust was generally not recommended.

A study of the voluminous literature on DDT that has appeared in the last 4 years indicates that little has been done with the compatibility of lime with DDT. Most of the work that has been done has been in conjunction with field testing of water suspensions of DDT with bordeaux mixture or with lime in concentrations generally used in whitewash. Those articles published describing decomposition effects of alkalinity and other chemical conditions on DDT were carried on at temperatures of 60° C. or above with most of them in the range of 100 to 125° C. Therefore, in planning these studies an effort was made to bring the factors involved within the range of conditions encountered in everyday use of lime-DDT combinations.

Studies in the laboratory were undertaken to furnish information in so far as possible on some factors involved in the breakdown of DDT by lime in dry mixtures using both quantitative chemical analyses and toxicity studies on the pink and green potato aphid, *Macrosiphum solanifolii* Ashmead.

Eastern Branch Program.

[1] The data contained herein are a portion of the results of research presented for the doctor's dissertation for partial fulfillment of the requirement for the Ph.D. degree in Entomology at Cornell University.

LABORATORY PROCEDURE.—In preparing dry mixtures of DDT and lime, the same standard procedure was followed throughout the work. The total amount of the original mixture was 200 grams. A proprietary band of 50 per cent wettable DDT powder was mixed with the various limes so that the finished product contained 3 per cent DDT. All lime samples used in these studies were obtained from commercial sources. Materials other than the limes were chemically pure.[1]

In each of the mixtures, after the proper amounts of lime and DDT were weighed, they were poured together into a 2-quart glass-topped, rubber sealed, mason jar. The jar was then vigorously shaken for a period of 10 minutes at the end of which time the mixture of lime and DDT was sifted through 20- and 40-mesh sieves, returned to the jar and thoroughly shaken again for another 2 minutes. The mixture was then considered properly prepared for sampling. Immediately before a sample was taken from a jar, the mixture was again thoroughly shaken. The sample consisting of 20 grams of the DDT-lime mixture, was added to 200 ml. of redistilled commercial benzene, the suspension shaken thoroughly for 2 minutes and filtered. The clear filtrate containing the DDT was then poured into 250 ml. Ehrlenmeyer flasks stoppered with tin foil and stored in a cold storage room at 40° F. In the interval between samplings, the jars containing the DDT-lime mixtures were placed in a darkened constant temperature room at 78° F.

An accurate method of analysis is needed in any study of DDT decomposition. Of the numerous available methods, the colorimetric method of Schechter *et al.* (1945) has proven to be consistently reliable after rather wide use. It is accurate to 10 micrograms or less and was chosen as the method to be used in these studies. The method consists of complete nitration extraction with ether followed by a series of washings with a dilute base and concentrated salt solution with the ultimate production of blue, violet red or red color by the addition of 10 per cent methanolic sodium methoxide. A colorimeter[2] with narrow band glass filters and standardized 22 mm. test tubes was used to measure the intensity of the colors developed.

Samples of pure p-p′ DDT, melting point 109.1° C., pure o-p′ DDT and pure 2, 2 bis (p-chorophenyl)-1,1 dichloroethylene (dehydrochlorinated p-p′ DDT) were carried through the procedure as standards in order to determine the amounts of these materials present in each sample analyzed. The extinction values of these pure materials were calculated from the transmission readings on the colorimeter at wave lengths of 640, 575, and 515 millimicrons. Assuming that the colors followed Beer's Law, an approximation, the values were used to derive equations which would give actual amounts of the three principal constituents concerned in DDT breakdown studies.

For determining the toxicities of DDT combined with various limes to the pink and green potato aphid, the same 200 ml. benzene extracts, described previously, which had been stored at 40° F. were used. Ten ml. of each benzene extract were pipetted into a test tube and evaporated to dryness. Thirty-two ml. of commercial acetone was then added and the tube shaken until the residue had dissolved. Eighteen ml. of distilled water was now added to the test tube which was shaken vigorously for 15 seconds before being used in the precision sprayer.

Contact toxicity tests were conducted on the endless belt precision sprayer as adapted from one described by Siegler & Munger (1935). Mature wingless potato aphids were placed in a 16-mesh screen cup 10 cm. in diameter and passed through the spray cone four times on the moving belt, the spray being applied at a pressure of 12 pounds per square inch. By using the screen cup, it was possible to shake all the smaller aphids through the mesh and to keep the spray from spattering after striking the bottom or sides. Approximately 50 aphids were employed for each treatment. The treated aphids were now transferred with a camel hair brush to clean lantern globe cages containing freshly cut clean potato leaves. Observations were made 48 hours after treatment and mortalities were recorded. Each treatment was replicated twice or, in some instances, three times. The lantern globes with the fresh foliage and treated aphids contained, were kept in a constant temperature room maintained at 78° F. with an

[1] *Pyrax ABB* Pyrophyllite was supplied from a commercial source.
[2] Lumetron Model 402E.

approximate relative humidity of 82 per cent. Controls or checks were used in all the experiments so that the mortalities of these controls could be utilized in correcting the mortalities of the treated aphids according to Abbot's Formula.

EXPERIMENTAL INVESTIGATIONS AND RESULTS.—Preliminary to a study of the reactivity of commercial limes with DDT, an investigation was made of the compatibility of DDT with some of the known materials that are either component parts of lime or its reaction products.

Although there was an indication of breakdown action of calcium hydroxide reagent and the high calcium lime after 4 hours' storage, the detection of larger losses of p-p′ DDT after 12 hours was definitely observed. In considering the results of these analyses in figure 1, it may be noted that the six materials occur in three general groups. Pyrophyllite, calcium carbonate and high magnesium lime fall into the group that produced little breakdown of DDT over the 16-day period. Magnesium oxide brought about measurable DDT

Table 1.—Decrease of p-p′ DDT content in several lime DDT combinations stored in a dry state at 78° F.

3% DDT 97% DILUENT AS INDICATED	PER CENT DECREASE BASED ON INITIAL SAMPLE FOR EACH TIME INTERVAL			
	After 2 Days	After 4 Days	After 8 Days	After 16 Days
High Calcium Limes:				
National Gypsum (Bellefonte, Pa., Source)	50.0	63.2	75.0	85.5
National Gypsum (York, Pa., Source)	47.0	48.2	61.4	74.7
Millard	53.2	64.5	70.9	91.1
Marblehead	54.8	57.1	52.4	79.8
Kelly Island	40.3	57.1	64.9	70.1
High Magnesium Limes:				
Allwood	14.1	30.6	36.5	42.3
Kelly Island	42.2	45.8	50.6	71.1
Ohio Hydrate	41.5	45.1	56.1	72.0
Millard	46.8	57.1	71.4	89.6
Warner's	58.4	63.6	81.8	92.2
Pyrophyllite	—	2.5	5.1	3.8

Materials included in this study were chemically pure calcium hydroxide, magnesium oxide and calcium carbonate. These were compared in a dry state with *pyrophyllite*,[1] a high calcium lime[2] and a high magnesium lime.[3]

Samples were taken for analysis as described above, immediately after mixing and at intervals of 4 and 12 hours, 1, 2, 4, 8 and 16 days. Graphic presentation of analyses data showing progressive decrease of p-p′ DDT with time is to be seen in figure 1. Figure 2 represents the rate of increase of the breakdown products with time.

The amount of p-p′ DDT contained in the original mixture was based on the analysis of the sample taken immediately after mixing. Analyses of samples taken after this period were considered in per cent decrease from this original figure.

[1] *Pyrax ABB* Vanderbilt Co.
[2] National Gypsum Co.
[3] Allwood Lime Co.

breakdown after 48 hours which slowly increased at a uniform rate through the last sampling. Calcium hydroxide and high calcium lime caused measurable breakdown of the DDT after 12 hours which increased very rapidly up to 4 days when approximately 75 per cent of the original amount of DDT had been lost. After 4 days there was a decrease in the rate of DDT degradation which continued through the 16-day period. The amount of breakdown products produced as calculated from the filter readings showed an increase at approximately the same rate as the amount of p-p′ DDT decreased (Fig. 2).

On the basis of these observations, it may be said that calcium hydroxide and a high calcium lime cause a marked breakdown of DDT in a dry mixture. Magnesium oxide has less effect on DDT breakdown than calcium hydroxide or the high calcium lime but a greater effect than pyrophyllite calcium carbonate, or the

high magnesium lime. Pyrophyllite, calcium carbonate and a high magnesium lime are relatively inert when combined with DDT.

These initial studies indicated that a difference exists in the tendency to cause DDT breakdown by various constituents of lime and various types of lime when these materials are combined in a dry state with DDT. On the basis of these observations, it may be predicted that certain of the ingredients in the so-called inert diluents have a marked effect on

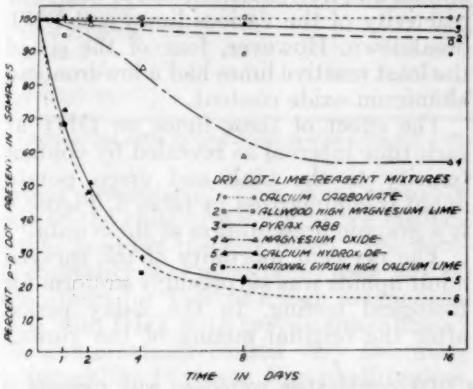

FIG. 1.—A decrease of P-P DDT in combination with hydrated lime and various lime constituents.

DDT and a study of similar types should be carried out. Thus a further investigation was promoted to observe the effects of a number of hydrated limes from different sources which are used rather widely for spray and dust purposes in New York and elsewhere.

The dry mixtures were prepared and handled in the same manner already described. Ten commercial limes plus pyrophyllite were included in the experiment. These limes are listed in table 1 and on figure 3, which presents the results of the analyses over 2, 4, 8 and 16-day periods and shows the per cent decrease of p-p′ DDT with time. Because the per cent increase in breakdown products closely followed the decrease in p-p′ DDT as was indicated in the preliminary study, it was not included in this writing.

There was a wide variation in activity of the various limes in causing breakdown of DDT. Those limes bringing about the greatest dehydrochlorination of DDT caused a 50 per cent decrease from the initial amount of p-p′ DDT in 2 days while those that were not quite as reactive showed a reduction of about 40 per cent in the same period of time. A high magnesium lime[1] does not fall into either of the above mentioned catagories. It caused a slower breakdown than the other limes,

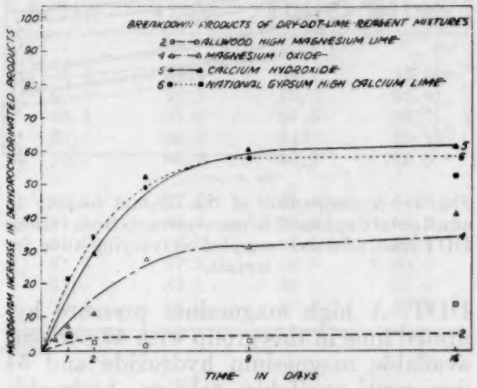
BREAKDOWN PRODUCTS OF DRY-DDT-LIME REAGENT MIXTURES
2 ALLWOOD HIGH MAGNESIUM LIME
4 MAGNESIUM OXIDE
5 CALCIUM HYDROXIDE
6 NATIONAL GYPSUM HIGH CALCIUM LIME
MICROGRAM INCREASE IN DEHYDROCHLORINATED PRODUCTS
TIME IN DAYS

FIG. 2.—An increase of dehydrochlorinated DDT in combinations of DDT with hydrated lime and certain lime constituents.

only about 25 per cent of the original amount of DDT being lost after 4 days and 40 per cent in 16 days. On the other hand, limes that were most reactive lost 80 per cent or more in the 16-day period. Pyrophyllite showed no reaction with DDT over the 16-day test period.

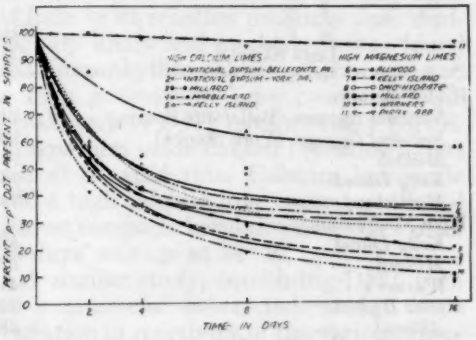

FIG. 3.—A comparison of the effects of various limes on P-P DDT breakdown when mixed and stored in a dry state.

To present an adequate explanation for the various results obtained is beyond the scope of this investigation. However, certain factors may be mentioned which perhaps possess some pertinence in relation to the analytical data. Five of the limes were derived from sources in Pennsylvania and, with one exception, all caused extreme and rapid breakdown of

[1] Allwood *Milk of Magnesia.*

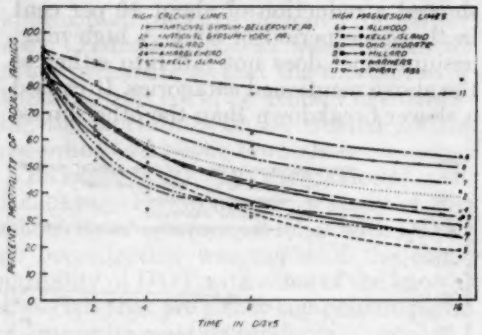

FIG. 4.—A comparison of the contact toxicity to adult potato aphids of benzene extracts from various DDT-lime mixtures sampled at varying time intervals.

DDT. A high magnesium pressure hydrated lime in this group with 42 per cent available magnesium hydroxide and 54 per cent available calcium hydroxide appeared more reactive with DDT at an earlier time interval. Those high magnesium limes that had their source in Ohio were less reactive than those mined in Pennsylvania and Missouri. These same limes from Ohio caused the least dehydrochlorination of DDT in comparison with DDT breakdown by limes from all sources, except one lime from Wisconsin.

In any discussion of DDT breakdown caused by lime, consideration must be given to the lime analyses. Table 2 presents a comparison of the calcium oxide, magnesium oxide, and total aluminum and iron oxide content in the samples studied. It may be noted that calcium oxide content for all 10 lime samples is rather uniform for the two types of lime. The magnesium oxide content is of little consequence in the calcium limes. Millard high magnesium has a rather low magnesium oxide content when compared with other magnesium limes.

Fleck & Haller (1945) have shown that aluminum and iron oxides are good catalysts for DDT degradation at high temperatures. The quantities of these two oxides in all the limes may be compared with the per cent decrease of p-p′ DDT after 16 days (Table 2). It may be seen that little correlation exists between aluminum and iron oxide content of degree of reactivity of the various limes and DDT breakdown. However, four of the six of the least reactive limes had a low iron and aluminum oxide content.

The effect of these limes on DDT at each time interval as revealed by contact toxicity to the pink and green potato aphid is summarized in table 3. Figure 4 is a graphic presentation of these data.

The per cent mortality of the sprayed adult aphids was surprisingly uniform for biological testing. In the 2-day period after the original mixing of the various limes and DDT, there was a rapid drop in mortality from 15 to 20 per cent for those DDT-lime combinations that effected a rapid breakdown of DDT. The mortality in 48 hours caused by DDT in combination with the high magnesium[1] limes dropped approximately 10 per cent. In the 4 and 8-day periods after the initial mixing, the per cent mortality varied

Table 2.—The decrease of p-p′ DDT in the lime DDT combination correlated with contents of calcium oxide, magnesium oxide, and total aluminum and iron oxides in the ten limes studied.

Lime Sample	Calcium Oxide	Expressed in Per Cent		Decrease of p-p′ DDT in 16 Days
		Magnesium Oxide	Aluminum & Iron Oxide	
High Calcium:				
National Gypsum (Bellefonte Source)	74.34	.47	.50	85.5
National Gypsum (York Source)	73.41	.91	.33	74.7
Millard	72.90	1.00	1.10	91.1
Kelly Island	73.15	.71	.76	70.1
Marblehead	74.45	.52	.37	79.8
High Magnesium:				
Kelly Island	48.49	34.47	.20	71.1
Millard	53.00	22.00	1.40	89.6
Warner's	41.62	30.17	.63	92.2
Ohio Hydrate	49.90	34.94	.38	72.0
Allwood	58.01	37.93	.96	42.3

[1] National Gypsum from Bellefonte, Pa., Millard high calcium and magnesium, Kelly Island high calcium and Marblehead high calcium.

Table 3.—An evaluation of the contact toxicity to the pink and green potato aphid of extracts from various DDT-lime dry mixtures sampled over a 16-day period.

SAMPLE FROM WHICH EXTRACT WAS MADE[1]	AVERAGE PER CENT MORTALITY IN 48 HOURS FOR EACH TIME INTERVAL				
	Initial	After 2 Days	After 4 Days	After 8 Days	After 16 Days
High Calcium:					
National Gypsum (Bellefonte, Pa., Source)	86.2	61.2	54.6	34.2	19.0
National Gypsum (York, Pa., Source)	81.8	68.2	59.3	55.8	33.4
Millard	87.9	63.4	51.6	31.6	16.7
Marblehead	91.7	67.5	46.3	44.1	30.2
Kelly Island	85.9	52.2	40.1	44.7	27.0
High Magnesium:					
Allwood	92.4	80.4	77.2	62.4	54.0
Kelly Island	84.5	74.1	66.8	57.5	40.9
Ohio Hydrate	89.2	81.5	69.8	55.1	46.9
Millard	91.3	61.3	57.8	42.3	30.6
Warner's	90.1	65.0	34.1	36.0	28.0
Pyrophyllite	94.0	89.4	88.0	77.1	82.7

[1] Acetone and water sprayed checks gave an average of 5.6% mortality.

rather irregularly. This was probably due to the close proximity to the median lethal dose for the test insect. The drop in mortality was more rapid than any of the others for Warner's high magnesium lime with DDT with certain other limes,[1] the combinations caused very low mortalities after 16 days. Pyrophyllite plus DDT produced a high mortality all through the test intervals.

In comparing the toxicity data with the results of the quantitative analyses over the test period, it may be noted that there is an excellent correlation of amount of p-p′ DDT present in the sample with its toxicity for the pink and green potato aphid. Pyrophyllite did not break down DDT at all, and the toxicity remained at the same high levels. Certain high magnesium limes[1] had the least effect on breakdown of DDT and the toxicities to the potato aphid were correspondingly high. On the other hand, others[2] gave rapid and practically complete breakdown of DDT in 16 days. The toxicities of DDT to the potato aphid when combined with these materials were the lowest obtained.

[1] *Allwood, Kelly Island* and *Ohio Hydrate.*
[2] *National Gypsum* from Bellefonte, Pa., Millard high calcium and magnesium and Warner's high magnesium limes.

SUMMARY.—A laboratory technique is described for the study of the effects of lime on DDT when mixed and stored in a dry state. These effects were studied using both quantitative chemical analyses and biological assay studies.

Using these procedures, the compatibility of DDT with some of the known materials that are either component parts of lime or its reaction products were studied. By analytical methods it was found that pyrophyllite calcium carbonate, and a high magnesium lime produced little breakdown of DDT over a 16-day period. Magnesium oxide caused breakdown, but not at a rapid rate. Calcium hydroxide and a high calcium lime caused rapid and almost complete breakdown of DDT after 16 days' storage at 78° F.

A similar study, combining DDT with 10 commercial limes, indicated a wide variation in reactivity of the various limes in causing breakdown of DDT. This dehydrohalogenation of DDT by the lime is closely correlated with toxicity to the pink and green potato aphid.

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The Bioassay of Gamma Benzene Hexachloride[1]

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Haller (1947) reviewed the physical, chemical, and biological methods of determining the constituents of technical benzene hexachloride. At the present time the results obtained by infrared absorption measurements (Daasch & Smith, 1947; Tufts & Kimball, 1947) are accepted as the most reliable. Widespread use of this method is handicapped, however, because of the expensive equipment and specialized training required. Biological assay of the gamma isomer content, although probably less precise and more limited in scope, yields the information most directly applicable to the insecticidal use of the material and can easily be carried out in the average laboratory without specialized equipment and personnel.

During a study of the relative toxicity of the isomers of benzene hexachloride to several insect species, the possibility of developing a method of bioassay was kept in mind. Several of the species tested were eliminated from consideration because of their susceptibility to the delta isomer, which would result in interference in the determination of the gamma isomer. Others showed variable susceptibility over a period of time or difficulties in maintenance of suitable cultures.

The red flour beetle, *Tribolium castaneum* (Hbst.), was found to be especially well suited for use as an assay organism. It was easily reared and once the culture had been built up, large numbers of insects were constantly available for testing. It was a sturdy insect showing little or no mortality in the checks. The toxicity curve for the gamma isomer was steep which would favor a high precision in the assay. The MLD of the gamma isomer determined in 1946 was 0.146 mg./g. and in 1947 was 0.142, showing the reproducibility of the curves. The toxicity of the impurities and isomers other than gamma were relatively low.

MATERIALS AND METHODS.—Standard stock solutions and working dilutions of technical benzene heptachloride and each of the five known isomers[2] of benzene hexachloride in redistilled acetone were prepared. These materials have been shown to constitute over 99 per cent of most commercial samples (Metcalf 1947). The insects were reared at a temperature of 78° ± 2° F. by placing several hundred adults in a tray containing whole wheat meal. After 2 weeks the adults were removed by sifting and the eggs allowed to hatch and the young to reach maturity in the trays. All tests were carried out on individuals which had been in the adult stage from one to two months.

A modification of the method described by Dobroscky (1935) was utilized in this study. One gram of finely ground whole wheat meal was placed in the center of a biological specimen dish so that it formed a small mound. The stock solution of the material to be used was diluted to the required concentration and 1.0 ml. was added to the meal by means of a pipette. The solution was worked into the meal with a spatula so that the meal was thoroughly wetted and intimately mixed with the toxicant. The acetone was allowed to evaporate. When the odor of acetone was no longer perceptible and the grain had been broken up and spread uniformly over the entire base of the dish, one hundred beetles were counted into the dish which was then covered with a double layer of cheesecloth. The dishes were then kept in a constant temperature room at 78° ± 2° F. By this method, the insects were exposed to entry of the insecticide by fumigant, contact, and stomach action. The dishes were not stacked but were placed side by side to give uniform aeration. Mortality readings were taken 8 days after treatment. Insects were considered dead only in the absence of movement after gentle prodding or warming with an electric light bulb held

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[1] These data are a portion of the results of research to be presented by the senior author in the dissertation for partial fulfillment of the requirements for the Ph.D. degree in Entomology at Cornell University.

[2] The alpha, beta, gamma, and delta isomers were separated from a commercial product and purified by the authors. The epsilon isomer and additional supplies of the beta and delta isomers were supplied by the Dow Chemical Company. All isomers were recrystallized shortly before use, and had the following melting points: Alpha, 160.2–160.9° C.; Beta, 310.2–310.6° with sublimation; Gamma, 113.8–114.1°; Delta, 138.4–139.4°; Epsilon, 220.8–221.8°. The benzene heptachloride was a technical product supplied by the California Spray Chemical Corporation, and had a melting range of 107.6–144.7°. Isolation of individual constituents of this material was not considered necessary because of the relatively low order of toxicity of the mixture.

several inches above the dish. Dosage was calculated on the basis of milligrams of toxicant per gram of whole wheat meal.

RELATIVE TOXICITY OF THE ISOMERS.—Table 1 presents the toxicity of the technical benzene heptachloride and the isomers of benzene hexachloride. Negligible mortality was obtained with the alpha, delta, and epsilon isomers at dosage levels 700 times the MLD for the gamma isomer, and with the beta at 350 times the gamma MLD. The benzene heptachloride was the only material other than the gamma isomer to show significant toxicity. However, its toxicity (MLD 27.6 mg./g.) was only about 0.5 per cent that of the gamma isomer (MLD 0.142 mg./g.). It should therefore cause no interference in the assay, since its concentration in commercial samples is normally less than that of the gamma isomer. Unless there is a combined effect in mixtures with the other constituents, the toxicity of a commercial sample of benzene hexachloride to this insect should depend only on the content of the gamma isomer.

Table 1.—Toxicity of benzene heptachloride and the isomers of benzene hexachloride. Data taken 8 days after treatment. Dosage is in terms of mg. of toxicant per gram of whole wheat flour.

Material	Dosage Mg. per g.	No. Insects Treated	Per Cent Mortality *Tribolium castaneum*
Alpha	100.0	200	0.5
Beta	50.0	200	1.0
Gamma	0.500	300	99.0
	0.400	300	99.3
	0.300	300	97.0
	0.200	300	78.3
	0.150	300	58.7
	0.125	300	34.3
	0.100	300	25.3
	0.090	300	12.3
Delta	100.0	200	3.5
Epsilon	100.0	200	1.0
Benzene	30.0	300	46.7
heptachloride	25.0	300	48.0
	20.0	300	34.0
	15.0	300	23.7
	10.0	300	2.0
Acetone		750	0.0

TOXICITY OF ARTIFICIAL MIXTURES OF THE ISOMERS.—In order to determine whether the presence of the other isomers or of benzene heptachloride might affect the toxicity of the gamma isomer to the red flour beetle, two mixtures of known composition were prepared. One (A) contained all of these constituents at equal concentrations, and the other (B) was prepared to approximate the composition of a typical commercial sample. Sample B contained alpha 70 per cent, beta 5 per cent, gamma 10 per cent, delta 6 per cent, epsilon 4 per cent, and benzene heptachloride 4 per cent (Metcalf 1947).

Table 2.—Toxicity of two mixtures of the isomers of benzene hexachloride and technical benzene heptachloride. Data taken eight days after treatment. Dosage is in terms of mg. gamma isomer per gram whole wheat meal.

Mixture	Dosage Mg. per G.	No. Insects Treated	Per Cent Mortality *Tribolium castaneum*
A. Contents at	0.50	300	100.0
equal level	0.40	200	97.0
	0.30	200	97.5
	0.20	500	87.4
	0.15	200	40.5
	0.10	500	17.2
B. Contents at	0.40	100	96
commercial	0.30	100	95
level	0.20	100	74
	0.10	100	25

Table 2 is a compilation of the toxicity of the two mixtures observed 8 days after treatment. In figure 1, the dosage mortal-

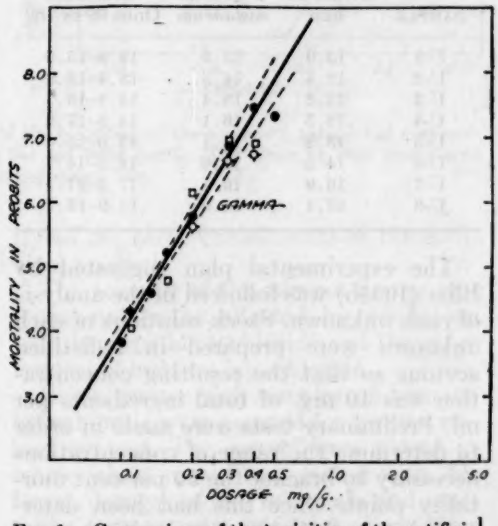

FIG. 1.—Comparison of the toxicities of the artificial mixtures (A and B) of isomers with the toxicity of the gamma isomer to the red flour beetle. The broken lines indicate the limits for the true values of the gamma dosage-mortality curve for odds of 19 in 20.

●——Gamma isomer
□——Mixture A
◇——Mixture B

ity data for each mixture in terms of the gamma isomer content were plotted as points with the standard gamma regression line which was calculated by the method described by Bliss (1935a, 1938). There was apparently no effect on the toxicity of the gamma isomer by the other isomers or the benzene heptachloride since the mortalities fell at random above or below the standard line. The absence of combined effects substantiates the results of Metcalf (1947) and differs from some of the results reported by Questel & Bowen (Haller, 1947).

BIOASSAY OF COMMERCIAL BENZENE HEXACHLORIDE.—Eight samples of commercial benzene hexachloride were assayed by this method. The samples were part of a group of materials from different sources distributed to various laboratories for cooperative tests of assay methods. The samples are designated in table 3 as U-1 to U-8.

Table 3.—Comparison of the gamma content of technical benzene hexachloride as determined biologically and with the infrared spectrometer.

SAMPLE	PER CENT GAMMA BY INFRARED	PER CENT GAMMA BY *Tribolium castaneum*	RANGE PER CENT GAMMA BY *Tribolium castaneum* ODDS 99 IN 100
U-1	13.9	13.9	12.5–15.4
U-2	12.4	14.5	13.4–15.8
U-3	13.2	15.4	14.2–16.7
U-4	13.5	16.1	14.8–17.4
U-5	13.2	14.1	13.0–15.4
U-6	14.0	13.6	12.5–14.7
U-7	16.9	19.1	17.3–21.1
U-8	12.4	14.0	12.9–15.2

The experimental plan suggested by Bliss (1935b) was followed in the analysis of each unknown. Stock solutions of each unknown were prepared in redistilled acetone so that the resulting concentration was 10 mg. of total ingredients per ml. Preliminary tests were made in order to determine the range of concentrations necessary to bracket the 50 per cent mortality point. Once this had been determined, two concentrations in duplicate of each material were applied as was previously described.

The mortality data observed 8 days after treatment were plotted and a line equal in slope to the standard gamma regression line was drawn through them (Fig. 2). The log-ratio of the potency of each material and its standard error were determined statistically and from these the apparent gamma content and the range within which it could be expected to fall in 99 out of 100 assays was calculated. The apparent gamma contents obtained by graphic comparison were very close to the values obtained by statistical computation and should be sufficiently accurate for most purposes.

The results of the infrared absorption analyses of these samples were made available through the courtesy of Dr. R. H. Kimball of the Hooker Electrochemical Company. The results of the two methods of analysis are compared in table 3. The samples were ranked in approximately the same order by both methods, but the actual values of the gamma isomer content were somewhat higher in most cases by the biological method. This has also been the case when the housefly and the milkweed bug were used for the assay of the gamma isomer (Haller 1947), and has resulted in the use of the term "gamma isomer equivalent" as a measure of the potency of technical benzene hexachloride as determined by bioassay.

DISCUSSION.—No effect on the toxicity of the gamma isomer by the other constituents of technical benzene hexachloride was shown in the study of the known mixtures. Three of the eight unknown samples assayed showed no significant differences which could be attributed to the method of determination. However, the other five showed significantly higher contents by bioassay than by infrared analysis. Further work will be necessary to determine whether the five higher results are explained by insufficient replication or other experimental error, or whether the higher results are normal and the lower results represent deviations. The experimental details were not sufficiently developed to bring out the precision of which the method is capable.

A number of improvements might be suggested in order to increase the precision of the method. Probably the most important would be to make each of the experiments self-contained by running several dosage levels, preferably at equal logarithmic intervals, of both the standard and unknown materials. This would correct for the daily fluctuations in susceptibility which could give rise to errors

in the apparent gamma isomer content when the unknown curve is compared with a master standard curve as in the present experiment. Replication of the assay over several days would also help to minimize the effect of daily variation. A closer control of environmental conditions would also eliminate some errors. In these experiments the insects were held at constant temperature but the treatments were made under variable temperatures, which might cause temporary differences in the activity of the insects and the volatility of the toxicant. Minor improvements might be made by substituting a less volatile solvent, such as ethyl alcohol, for the acetone to reduce errors in concentration of the solutions due to evaporation. Use of a flour of more uniform particle size might insure a more even distribution of the toxicant.

A shorter period of observation might be considered advantageous for convenience in assay. However, at the earlier periods, the mortality was still rapidly increasing with time and the results were less reproducible. Determination of the dead individuals was also difficult. At the later periods the mortality had reached a nearly constant level and differentiation between dead and live individuals was easier.

SUMMARY.—*Tribolium castaneum* was chosen as a test insect for the determination of the gamma isomer content of commercial benzene hexachloride because of easy rearing, low natural mortality, a steep and reproducible toxicity curve with the gamma isomer, and a low susceptibility to the other constituents of the technical product.

The toxicity of the gamma isomer was found not to be affected by admixture with benzene heptachloride and the other isomers of benzene hexachloride.

Eight commercial samples of benzene hexachloride were assayed for gamma isomer content. The insects were placed in whole wheat meal impregnated with different dosages of the materials and mortality counts were made 8 days after treatment. The mortality curves of the unknown materials were compared with a standard gamma isomer regression line and the apparent gamma content was computed statistically.

The results were compared with analyses made by the infrared method. Three

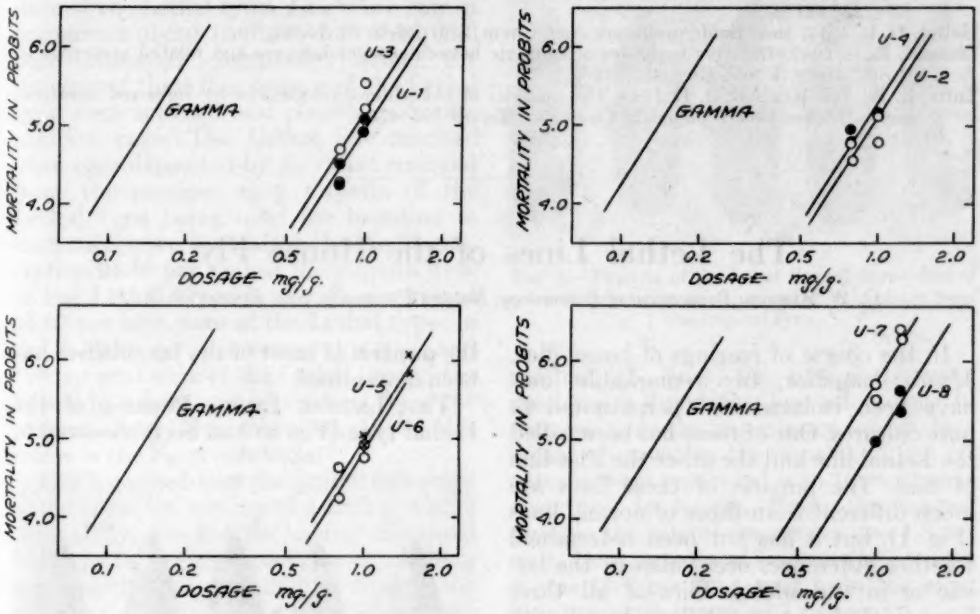

FIG. 2.—Comparison of the dosage-mortality curves of the toxicities of the unknown samples of commercial benzene hexachloride and the gamma isomer to the red flour beetle. The slope of each curve was that of the gamma regression line.

determinations agreed within the experimental error and five were significantly higher than the infrared results.

A number of improvements over the preliminary procedure were suggested.

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The Lethal Lines of the House Fly

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In the course of rearings of house-flies, *Musca domestica*, two remarkable lines have been isolated and perpetuated in pure cultures. One of these has been called the Lethal line and the other the Flat line of flies. The puparia of these lines are much different from those of normal lines (Fig. 1), but it has not been determined whether differences occur also in the larvae or in the adults. Flies of all three lines (including normal flies) breed with one another readily.

FIG. 1.—Average normal puparia of *Musca domestica*.

Since July, 1946, when the Lethal line was discovered, more than 2,000,000 puparia from nearly 1,000 standard jar cultures of the Lethal, the Flat, or of Normal lines have been sorted as to type, and the weight of sample lots have been recorded. The rate of emergence of flies from the puparia of most of the jar cultures has been determined.

THE LETHAL LINE.—Puparia of the Lethal type (Fig. 2) had been observed in

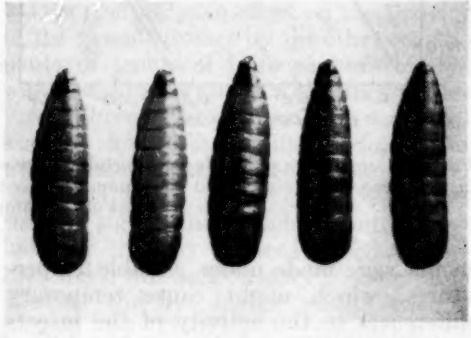

FIG. 2.—Puparia of the lethal line of house-flies of an early generation.

cultures of two laboratory lines of flies prior to July, 1946. Each line had been bred in a different laboratory for at least a year previously. Lethal puparia also were found among those of wild flies collected from horse manure at New Brunswick. In all cases they were present in occasional jar cultures at a rate of a fraction of 1 per cent of the population, and although they were discarded regularly from the stocks used for breeding, they continued to be found in each successive generation.

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The standard artificial medium used as food for house-fly maggots in the laboratory is capable of providing nutrients for several successive generations. In one jar in which a brood of maggots had developed and which had been left uncovered, eggs were deposited by a free fly. These eggs produced a brood of unusually large and uniform flies. Examination of the puparia from which these flies had emerged showed that about 2.5 per cent were of the Lethal type. This was a rate of occurrence about 10 times that which had been observed previously. From the progeny of these flies pupara of the Lethal type were selected and placed in an oviposition cage. The Lethal line resulted from eggs deposited by flies that emerged from the puparia, only puparia of the Lethal type being used for breeding in each successive generation. In the F_1 generation 94.42 per cent of the puparia were of the Lethal type; in the F_2 generation 94.67 per cent were of the Lethal type; in the F_3 99.98 per cent were of this type, and 100 per cent were of the Lethal type in the F_4 and in subsequent generation. As of the present date (November 20, 1947) this line is in the F_{27} generations.

It is supposed that the Lethal line originated from the mating of a Lethal with a normal fly, the female having deposited her eggs in the discarded jar of medium mentioned. Since the size and vigor of the resulting flies indicated that they may have been hybrids, the parent flies may have originated from the two lines of normal flies being studied at the time.

When normal larvae become full grown they retract their mouth parts and foreshorten and in this way become the somewhat elongated and rounded normal puparia. Full grown larvae of the Lethal line observed at this time seem to be unable to maintain the mouth parts in a retracted position such as is characteristic of normal larvae. Time after time they retract their mouth parts, but they always extrude again into the position they occupy when the larvae are feeding. Although this subject needs much further study it seems possible that the principal characters of the Lethal puparia—the elongated shape with open pore anteriorly —may result because the larvae are unable to retract their mouth parts normally when forming the puparia.

The ability of flies to emerge from lethal puparia depends, in part at least, on their shape. Whereas puparia of the Lethal line were very uniform in shape in the early generations, they have become more variable in time (Fig. 3). The rate of emergence is least from the most elongated puparia and greatest from the most blunt individuals. One reason why few flies emerge from the elongated puparia is

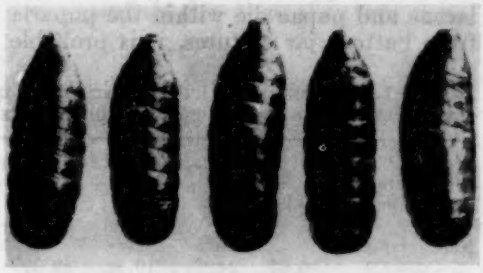

FIG. 3.—Puparia of the lethal line of house-flies of a recent generation showing variation in shape from the original type.

mechanical, since the puparia-bursting mechanism functions less effectively in proportion as the puparia are longer. In a recent observation the puparia of one jar culture were separated into three groups according to length. From the longest puparia the rate of emergence was 1.8 per cent, from puparia of intermediate length it was 10.2 per cent, and from the most blunt puparia it was 42.1 per cent.

Besides offering interference with normal emergence of flies because of shape, the puparia protect the pupae within much less effectively because of the pore at the anterior end, which is always open although variable in diameter. Often larvae that feed longer than others in a given culture enter the open pore of individuals that pupated earlier and behave as animals devouring the unprotected pupae within. This cannibalistic behavior, which is almost unknown among the individuals of normal lines, increases in proportion as populations are greater when, because of competition for food, the larvae are less well nourished and are still hungry when the nutrients of the culture are exhausted.

Thus far the lethal line has been studied only in the laboratory, and the rate of emergence has been determined when the puparia were placed in glass jars. Under natural conditions, when the larvae form their puparia in the earth or in

manure piles, the open pore may cause them to be susceptible to attack by bacteria, small predacious insects, and other organisms that cannot penetrate normal puparia. Under these conditions it is probable that fewer flies will survive and emerge from puparia of the Lethal line than is the case under laboratory conditions.

Since many, but a varying percentage, larvae and pupae die within the puparia from battery jar cultures, it is probable that some of this mortality is caused by bacteria or other microorganisms, the complex of which appears to vary in different lots of the medium for, whereas fermentation that is favorable to the larvae usually occurs, rotting, which is unfavorable, is sometimes observed.

The average rate of emergence of flies from puparia of the lethal line was 29.6 percent in the F_1 generation. Subsequently it has varied. In the first 12 generations the entire lot of puparia from one jar of larval medium was used for breeding, but from the 13th to the 27th generations puparia have been selected and those most like the originals have been used for breeding in an effort to fix the type. The average rate of emergence was greatest in the F_{11} (60.8 per cent) and least in the F_{20} (12.2 per cent). The rate of emergence has been consistently greater from puparia of a lethal line where selection has not been practiced. From puparia of normal lines of flies the rate of emergence usually is between 90 and 95 per cent under laboratory conditions.

RESULTS OF CROSSING.—Puparia of the lethal line and of three normal lines were isolated in vials. When the flies emerged their sex was determined and males or females of the lethal line were placed in oviposition cages with flies of the opposite sex of one of the normal lines. The six resulting hybrid lines were carried for 10 generations and were then discarded. In each generation of each hybrid all individuals of one jar culture were used for breeding.

The average rate of occurrence of lethal puparia in the progeny during 10 successive generations was similar for each cross involving each normal line, as shown in table 1. Usually there was little if any increase in the incidence of lethal pu-

Table 1.—Percentages of lethal puparia found in the F_1 to F_{10} generations of crosses in bulk of each sex of flies of three normal lines with the opposite sex of the lethal line.

SOURCE OF FLIES	PERCENTAGE OF LETHAL PUPARIA FOUND IN THE FOLLOWING GENERATIONS									
	1	2	3	4	5	6	7	8	9	10
Nelson females[1] × Lethal males	0.67	24.28	19.82	15.37	10.42	8.21	11.32	8.20	6.36	5.77
Nelson males × Lethal females	0.57	25.13	15.71	16.53	9.49	6.62	6.87	5.80	7.66	4.87
Rutgers females[2] × Lethal males	4.35	23.74	18.96	14.53	12.88	15.22	8.67	8.05	8.83	9.68
Rutgers males × Lethal females	2.55	23.51	14.71	12.38	12.67	7.42	8.22	5.45	6.87	7.03
Wild females[3] × Lethal males	0.03	25.65	20.29	15.56	18.16	12.77	11.16	10.40	10.62	10.95
Wild males × Lethal females	0.15	24.87	19.62	22.62	23.63	10.07	10.16	12.61	10.70	9.86

[1] A line obtained from the Standard Oil Company, Bayway, N. J.
[2] A line obtained from Boyce Thompson Institute, Yonkers, N. Y.
[3] A line from puparia collected from a pile of horse manure at New Brunswick, N. J., fall, 1946.

paria in the F_1 generation over those found in the normal lines, but in the F_2 generation approximately one-fourth of the puparia were of the Lethal type. Thereafter the rate of occurrence of Lethal puparia decreased regularly, but it remained at a somewhat higher level in crosses involving the wild line, which originated from puparia collected from horse manure in early fall, 1946.

BEHAVIOR IN FOODS OTHER THAN THE STANDARD LARVAL MEDIUM.—From time to time larvae of the Lethal line, as well as of normal lines, have fed in horse manure, in guinea pig manure, in roach dung, and in a synthetic medium similar to that used for maggots of blowflies. In all of these media all of the puparia have been of the Lethal type, and they were similar to those found in cultures in the standard larval medium at a corresponding time.

BEHAVIOR IN DIFFERENT POPULATION LEVELS.—When smaller or larger numbers of larvae feed in a standard jar of medium the resulting puparia are larger or smaller in proportion to the level of the population, but the puparia of any population are quite uniform in size. The extreme range in size of the puparia observed in normal lines is from about 0.003 gram to about 0.036 gram. The puparia of the lethal line show a similar range in size under like conditions, and in populations ranging from a few hundred to more than ten thousand per jar culture all have been of the Lethal type.

PROPORTION OF SEXES.—Determinations of the sex of flies that emerged from the lethal puparia, from puparia of normal lines, and from the crosses, showed that in all cases the percentages of males and females were equal.

COMPARISON OF THE WEIGHT OF PUPARIA.—Sample lots of puparia, usually 5 or 10 groups of 100 each, from each jar culture of all lines and crosses have been weighed. Although the average weight of the puparia has varied somewhat when the populations were equal, probably reflecting differences in the larval medium, and varied directly with the populations, the evidence shows that the weight of puparia of the lethal line, and of the lethal puparia of the crosses, was approximately the same as that of puparia of the normal lines or of the normal puparia of the crosses.

THE FLAT LINE.—The flat line of house-flies was established in November, 1946 from puparia of this type found in a culture originating from puparia collected from horse manure out-of-doors previously. These insects have been studied to determine whether they could be established as a pure culture as had been done with the lethal line previously. The puparia of the Flat line (Fig. 4) are remarkable in that they are somewhat flattened, rather rectangular in shape, with very distinct segments. Characteristically they do not have open pores, although individuals of the lethal type are more plentiful than in normal lines. Emergence from puparia of the flat line averaged about 80 per cent in the first 10 generations, but in recent generations it has fallen to about 63 per cent, and emergence from the most typical puparia has recently been about 40 per cent.

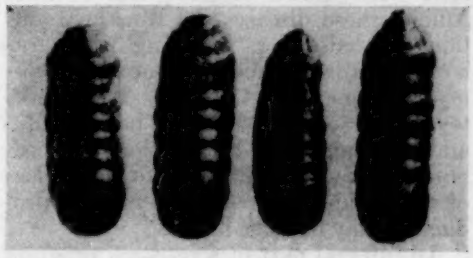

FIG. 4.—Puparia of the Flat line of house-flies.

As of November 20, 1947, this line was in the F_{16} generation. Normal puparia occurred in cultures of the flat line until the F_{12} generation, although these were regularly discarded and only puparia typical of the line were used for breeding. The flat line is remarkable because of the feeding efficiency of the larvae, which grow to a larger size and produce a greater biomass from the same volume of larval medium than is usually the case with other house-flies.

DISCUSSION.—Although lethal genes of *Drosophila* have been investigated, as far as we know lethal lines of injurious insects have not been known heretofore. Therefore, there is no precedent or experience whereby we can be guided in judging their usefulness to man. We are investigating these lines of flies with a view to determining whether lethal lines of insects can be used in biological control of injurious species.

Biology of the Lone Star Tick in the Laboratory[1]

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The discovery by Smith & Kilbourne (1893) that the causative agent of Texas Fever was transmitted by the tick, *Boophilus annulatus*, stimulated interest in the economic importance of ticks. Subsequently, a number of disease organisms have been shown to have tick vectors. Among these diseases are Rocky Mountain spotted fever, relapsing fever, tularaemia, anaplasmosis, equine encephalomytes, American Q fever, and bullis fever. The feeding of ticks is both painful and discomforting. In addition, the economic loss due to damage to hides, loss of weight and the reduction of milk production may be considerable.

An integral part of a research program designed to investigate chemicals as possible tick toxicants and repellents was the maintaining of a colony of standardized test organisms. For our purpose the lone star tick, *Amblyomma americanum L.* was used.[2]

LABORATORY HOST AND INFESTATION METHODS.—Rabbits were employed exclusively as the host animal.

The method used for infesting the rabbit is a modification of the capsule-technique as described by Morton (1929). The rabbit is closely shaved on its sides between the fore and hind legs. Tin pillboxes, 1.75 inch in diameter, are used as capsules. A hole, 1.25 inch in diameter is cut out of the bottom of the pillbox. The bottom of the capsule is attached with cement to a piece of chamois cloth which has a hole slightly less than 1.25 inch in diameter. One capsule is attached to each side of the rabbit by coating the chamois with the cement. Two quarter-inch holes are drilled in the cover of the capsule. On one of these holes is soldered a piece of stainless steel, 100-mesh, wire cloth. This permits sufficient air circulation in the capsule to prevent moisture from condensing in it. The other hole is used as an entrance point for the placing of nymphs and adults in the capsule. Adhesive tape is used to cover this hole and fasten the cover of the capsule to the bottom portion of the pillbox. In order to prevent the rabbit from dislodging the pasted capsules, a sheet-rubber guard is wrapped around the animal to cover the capsules. The guard is fastened with two 3-inch safety pins.

INOCULATION.—As will be described below, the ticks are kept in holding tubes, the bottoms of which are stoppered with fine mesh wire cloths.

Through the wire cloth a stream of carbon dioxide is passed, which quickly anesthetizes the ticks. The tube is then retained in carbon dioxide saturated air so that the ticks will not become active when the cotton plug stopper is removed during the process of transferring the ticks to the host animal.

As many as four male and four female ticks can be placed in each capsule through the quarter-inch hole in the cover of the pillbox. As many as 50 unengorged nymphs are inoculated in each capsule in the same manner and about 500 immobilized larvae are brushed into the capsule so that they come in contact with the skin of the rabbit.

It is important that the unengorged seed ticks come in direct contact with the clean-shaven skin of the animal. Another precaution which should be taken is to allow the cement to dry thoroughly before the ticks are placed in the capsule, otherwise the solvent used in the paste will act as a fumigant.

The same capsule can be utilized for two or three inoculations if the rabbit is inoculated with seed ticks or nymphs, but after adults have engorged it is expedient to remove the capsule.

THE HOLDING TUBE.—As will be shown below, the humidity requirements of ticks are quite high. Thus, a new type holding vial was constructed, which although eliminating condensed moisture, enables the ticks to be surrounded with a moist atmosphere and permits the rapid immobilization of the ticks with carbon dioxide.

The holding container consists of a tube

Eastern Branch Program.

[1] Journal Series Paper, New Jersey Agricultural Experiment Station, Rutgers University, Department of Entomology. Research Fellowship sponsored by Carbide and Carbon Chemicals Corporation.

[2] The original supply of these ticks was obtained from Carrol N. Smith of the Federal Bureau of Entomology and Plant Quarantine.

of soft glass, five inches in length and one-half inch in diameter, plugged at one end with cheesecloth wrapped absorbent cotton and at the other end with a specially prepared cork which serves to hold a cotton wick. A three-eighth inch diameter hole is cut out of the center of a number three cork which has been cut to 0.25 inch in length. The cork is covered on its upper and lateral surfaces with a 100-mesh stainless steel wire cloth. The covered cork is placed 0.75 inch from the bottom of the tube and a few drops of melted paraffin are used to seal the circumference of the cork to the inner surface of the glass tube. One end of the cotton dental wick, 5 inches in length, is placed in the tube and fastened with adhesive tape to keep it in contact with the bottom surface of the cork. The other end of the wick is placed in distilled water, and thus supplies the necessary moisture for the ticks.

LIFE HISTORY STUDIES.—*Eggs*—The eggs of *Amblyomma americanum* are deposited in a sticky mass in front of the engorged female. The depth of egg color, varied considerably among egg masses, ranging from a dark, reddish brown, to a light tan, or a lemon yellow in extreme cases. The color of the eggs within the same egg mass, however, is rather constant.

The number of eggs laid by engorged females varied. Counts made of 31 egg masses showed a range of 260 to 9000 eggs with the mean number about 3420.

The weight of a single egg averages .054 mg. with a maximum of .058 mg. and a minimum of .046 mg.

The average ratio in per cent of the weight of the eggs to the weight of the engorged female is approximately 40 with a minimum of 3 and a maximum of 70.

Upon hatching, the egg shell splits at one end, and this split continues for almost three-quarters of the length of the egg. There was generally 70–90 per cent hatching of the eggs, but in some masses, the hatching was as low as 5 per cent.

The mean length of the incubation period of the egg masses at 30° C. was 25 days; at 28° C. there was a mean of 33 days.

ENGORGEMENT OF LARVAE.—At room temperature (21° C.) the longevity of larvae kept in the holding tubes was about 10 weeks.

In the method of inoculating larvae, which was described above, the larvae soon recover from the carbon dioxide immobilization. They then distribute themselves evenly over all the skin available within the capsule. Within a short period most of the seed ticks come to rest and insert their mouth-parts into the host.

There are no visible signs of engorgement of the larvae during most of the period that they are attached. Noticeable enlargement occurred a few hours before the larvae have fully repleted, and were ready to detach from the host. From an estimated 15,050 larvae that were inoculated, a total of 10,946, or approximately 73 per cent of the larvae completed engorgement.

The average weight of a 6 week old unengorged larva is .044 mg. When fully engorged, larvae weighed from .95 to 1.35 mg. with a mean of 1.05 mg. This is an approximate 24 fold increase in weight after feeding.

The period of time required to complete engorgement of approximately 11,000 seed ticks are shown in table 1.

Table 1.—Time required for the engorgement of larvae.

Day After Inoculation	Larvae Engorged on Stated Consecutive Days	
	Number	Per Cent
3	114	1.2
4	3,611	33.0
5	4,216	38.5
6	1,957	17.8
7	715	6.5
8	284	2.6
9	27	.2
10	23	.2
Total	10,946	100.0

As shown in table 1, almost 90 per cent of the larvae completely engorged on the 4th, 5th, and 6th days, and over 70 per cent of the engorged large dropped on the 4th or 5th day.

MOULTING OF ENGORGED LARVAE.—After dropping, the engorged larvae crawl about within the capsule in an effort to find some crevice in which to rest. When the engorged larvae are placed into holding tubes, they come to rest throughout the tube, often concentrating around the cotton plug.

There are no externally visible signs of

the moulting process for several days after the larva detach. Gradually, the body mass of the larva concentrate at the posterior end of the old larval skin. Within a day or two before the ecdysis, the lateral and anterior margins of the engorged larva became hyaline.

The old larval skin splits transversely starting at the vertex of the posterior end.

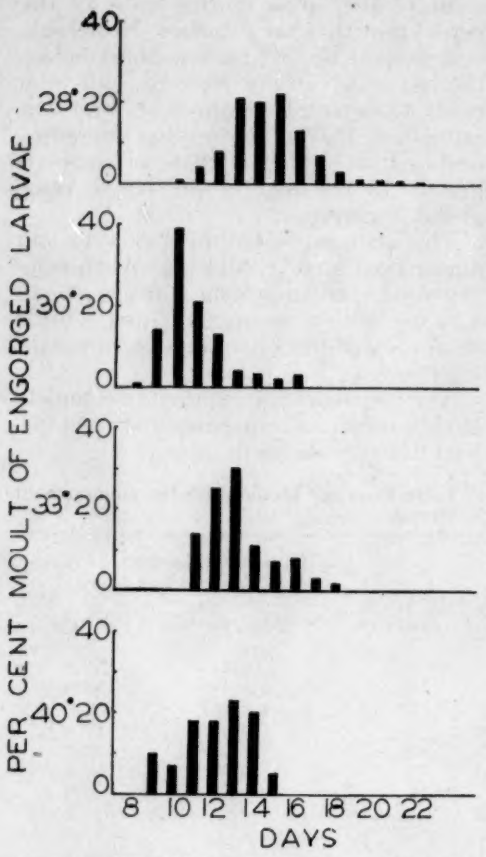

FIG. 1.—Effect of temperature on moulting of engorged larvae.

This split continues anteriorly along the lateral margins until the dorsal and ventral halves are connected only at the head end. The posterior portion of the newly moulted nymph protrudes first.

The per cent of the engorged larvae that successfully moult and the time required for the moulting period depended upon the temperature and relative humidity. Table 2 shows the effect of temperature on the number of engorged larvae that moulted.

Figure 1 graphically compares the percentage moult for engorged larvae kept at 28° C., 30° C., 33° C. and 40° C. that occurred on each day.

At 30° C. engorged larvae started to moult the eighth day. This was from 1 to 3 days prior to those kept at the other temperatures. The last engorged larvae that moulted were those kept at the lowest temperature, 28° C. This was from 4 to 7 days later than those at the other temperatures. The last moult occurred on the fifteenth, sixteenth, and the eighteenth day after repletion at the temperatures of 40° C., 30° C., and 33° C., respectively.

The curve representing the moulting of engorged larvae kept at 28° C. has a

Table 2.—Effect of temperature on the number of engorged larvae that moulted.

TEMPERATURE DEGREES C.	NO. ENGORGED LARVAE	NO. MOULTED	PER CENT MOULTED
4	20	0	0
20	40	22	55
28	1,532	1,349	88
30	1,620	1,512	93
33	380	313	83
40	150	61	41

broad base ranging from 10 to 22 days, with the peaks occurring on the thirteenth fourteenth, and fifteenth days. Engorged larvae kept at 30° C. had their peak moult on the tenth day, approximately four days prior to those kept at 28° C. At 33° C. the engorged larvae moulted with the peak at the twelfth and thirteenth days. This was faster than those kept at 28° C., but slower than those kept at 30° C. At 40° C. the peak moult of engorged larvae occurred from the eleventh to the fourteenth day. From the data presented on the moulting of engorged larvae, it can be concluded that 30° C. is the optimum temperature or is closer than the other temperatures to this optimum.

The importance of humidity in the laboratory rearing of ticks has been recognized by several investigators. Gregson (1942) claimed that the humidity requirements for practically all Ixodids was very high, even 100 per cent relative humidity, although condensed moisture should be avoided. Howell (1939) reared *Dermacentor albipictus* Pack. in the lab-

oratory and stated that ticks in all stages of development preferred a relative humidity of above 70 per cent, and many chose one over 85 per cent.

In order to determine at what relative humidities there would be the greatest survival in the moulting of engorged larvae, tests were conducted in which the relative humidities were varied from 72 per cent to 100 per cent. The desired relative humidities were obtained by utilizing saturated salt solutions. The results of the effect of relative humidities on the moulting of engorged larvae kept at 28° C. and 30° C. are shown in tables 3 and 4.

Table 3.—Effect of relative humidity on moulting of engorged larvae. Temperature at 28° C.

Per Cent Relative Humidity	Chemical	Number in Test	Number Moulted on Consecutive Days						Total Number Moulted
			10	11	12	13	14	15	
100	H_2O	20	0	0	1	13	2	4	20
92	K_2SO_4	20	0	0	1	4	11	3	19
91	KNO_3	20	0	0	6	2	3	4	15
87	Na_2CO_3	20	0	0	2	3	13	1	19
83	KCl	20	3	6	7	0	0	1	17
79	$(NH_4)_2SO_4$	20	3	1	5	2	2	2	15
72	NH_4Cl	20	4	1	0	0	1	0	6

Table 4.—Effect of relative humidity on moulting of engorged larvae. Temperature 30° C.

Per Cent Relative Humidity	Chemical	Number in Test	Number Moulted on Consecutive Days								Total Number Moulted
			8	9	10	11	12	13	14	15	
100	H_2O	45	0	17	19	3	1	2	0	0	41
92	K_2SO_4	45	0	26	16	0	1	0	0	0	43
91	KNO_3	45	2	18	15	1	4	0	1	0	42
87	Na_2CO_3	45	2	15	21	2	2	1	0	0	43
83	KCl	45	0	5	10	5	12	3	3	0	39
79	$(NH_4)_2SO_4$	45	0	1	10	8	13	2	1	2	37
72	NH_4Cl	45	0	0	9	5	9	6	1	6	36

At both 28° C. and 30° C. the greatest number to moult were those kept at relative humidities from 100 to 87 per cent. There was a gradual reduction in the number moulted as the relative humidity was decreased. In contrast with the experiments conducted at 28° C. in which those engorged larvae kept at relative humidities of from 83 to 72 per cent moulted first, at 30° C. the converse happened.

ENGORGEMENT OF NYMPHS.—The unengorged nymphs can be kept at room temperature (21° C.) in the described holding tube for 22 weeks, without noticeable mortality.

The nymphs attached to the host within a few hours. As with larvae, engorgement is not apparent for the first days of attachment, but becomes noticeable, approximately 2 days before the fully engorged nymphs detach.

The mean weight of unengorged nymphs 19 weeks old is .24 mg. When fully engorged their average weight is 8.9 mg. representing a 37 fold increase.

Of 1265 nymphs inoculated, 1015, or approximately 80 per cent completed engorgement. Records taken to determine the time necessary for engorgement of 913 nymphs are shown in table 5.

MOULTING OF ENGORGED NYMPHS.—Upon completion of engorgement, the nymphs are placed in the holding tubes,

Table 5.—Time required for the engorgement of nymphs.

Day After Inoculation	Nymphs Engorged on Stated Consecutive Days	
	Number	Per Cent
3	1	.1
4	302	33.3
5	316	35.5
6	191	20.9
7	80	8.7
8	13	1.4
9	8	.9
10	2	.2
Total	913	100.0

where they crawled about actively in an attempt to find a suitable site to lodge. They come to rest throughout the holding tube, securing themselves on the cotton plug, sides of the tube, or on the bottom of the tube.

For about a week, there are no visible signs of the moulting process. Thereafter, the anterior portions of the engorged

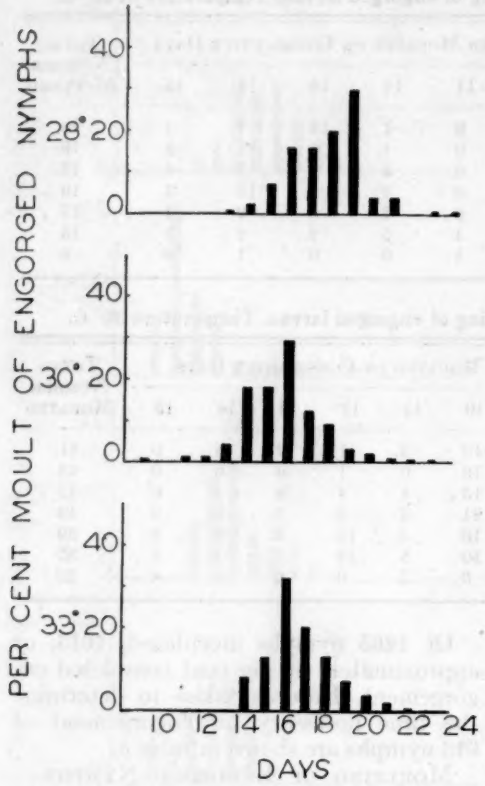

FIG. 2.—Effect of temperature on moulting of engorged nymphs.

nymphs become hyaline, with the darkened body mass concentrating at the posterior end of the old nymphal skin. Within two or three days before ecdysis, the external features of the adult are in evidence.

The nymphal skin splits transversely at the ventral posterior end and this split continues anteriorly along the lateral margins. The posterior portion of the adult protrudes first, and with the aid of the hind legs it manages to escape from the old nymphal skin. The actual ecdysis may take several hours.

Fifteen engorged nymphs were kept at 20° C., and only one male emerged. From 217 engorged nymphs kept at 28° C., 213, or about 98 per cent, developed to adults. At 30° C., 208 of 209, or practically 100 per cent, moulted. There was 100 per cent moult when 112 others were kept at 33° C.

The time required for engorgement has no effect on the time necessary to moult. The time required to moult depends to some extent on the temperature at which the engorged nymphs are kept. Figure 2 shows the time necessary to moult for nymphs kept at 28° C., 30° C., and 33° C.

As shown in figure 2 a range of from 13 to 24 days was required for the engorged nymphs kept at 28° C. to moult, but 82 per cent of them moulted on the sixteenth to ninteenth days. Of those kept at 30° C., 9 to 23 days were necessary for all of them to moult, however 77 per cent of the engorged nymphs moulted on the fourteenth to seventeenth days. At 33° C., there was a range of from 14 to 22 days, with 77 per cent moulting on the fifteenth to eighteenth days. Since the moulting of the engorged nymphs occurred somewhat sooner at 30° C. than at either 28° C. or 33° C. it was felt that this temperature should be utilized.

Although not shown in figure 2, at 28° C. both males and females required the same amount of time to emerge; however, at both 30° C. and 33° there was a definite tendency for the males to emerge first. At the lower temperature there was an equal number of males and females produced, but at the higher temperatures almost twice as many females as males emerged.

ENGORGEMENT OF ADULTS.—The time of initiation of feeding by adult ticks varies considerably. It has been noticed that some adults insert their mouth parts immediately upon reaching the surface of the host while the majority of them wander about within the capsule for a number of hours before attaching. Others do not attach for 2 to 3 days, and some adults never attach and eventually die. The male often attaches before the female.

Once the female is attached, she rarely moves; however, the male frequently moves within the capsule during the period of attachment. Fertilization of the female occurs on the host while the adults are feeding. Both the male and the female feed before copulation. The male seeks the

female and reattaches to the host beneath the site of attachment of the female in such a manner that the ventral surface of the male makes contact with the ventral surface of the female.

The male does not show marked enlargement throughout its feeding period although some males remain attached for as long as 20 days after the female has detached.

The time necessary to complete engorgement of 90 adult females, computed from the date of inoculation to the date of detachment varied from 9 to 23 days, with a mean of 13.5 days. Approximately 70 per cent of the females completed engorgement within the 12 to 16 day period. The average weight of week-old females is 6.0 mg., while the average week-old male weighs only 3.2 mg. When fully engorged the average female weighes 451 mg. with a maximum of 710 mg. This is a 79 fold increase in weight.

OVIPOSITION.—The female may oviposit almost immediately, or wait several weeks, before initiating oviposition. There seems to be no correlation between the time of engorgement and the preoviposition period, nor is there any apparent relationship between the number of eggs laid and the preoviposition period.

The time interval between the date of dropping from the host and the beginning of egg deposition for 47 engorged females varies from 1 to 29 days. The mean preoviposition period is 6.5 days.

The oviposition period has, in some cases, lasted over 2 weeks.

SUMMARY AND CONCLUSIONS.—The lone star tick, *Amblyomma americanum* (L), can be successfully reared in quantity in the laboratory. The rabbit is a satisfactory host animal on which 73 per cent of the inoculated larvae, and 80 per cent of the inoculated nymphs successfully replete.

A modification of the capsule method is utilized for infesting the host animal.

From the data presented, 30° C. is closest to the optimum for the moulting of engorged larvae and engorged nymphs.

A relative humidity of from 85 to 100 per cent is most favorable.

The average life cycle when all stages are incubated at 30° C is as follows: The engorged female lays 3500 eggs, which require an incubation period of 25 days. The larvae engorge in from 4 to 5 days, from which the nymphs moult on the tenth day. The nymphs engorge after 5 days feeding, and the adults emerge after 16 days. The fertilized female engorges on the thirteenth day after attachment, and begins oviposition 7 days later. The average time to complete a generation is therefore 81 days. In laboratory practice, 2 weeks are allowed between the ecdysis and reinoculation. Thus the complete life cycle can be obtained in approximately 4 months.

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DR. CREIGHTON TO GO TO CENTRAL AMERICA

Dr. John T. Creighton, Head of The Department of Entomology of The University of Florida has taken professional leave from the University in order to accept an assignment at the Inter-American Institute of Agricultural Sciences. The Institute is located at Turrialba in Costa Rica.

Doctor Creighton will be charged with the responsibility of projecting a research program for the Institute in the field of entomology. This will necessitate a survey of the major insect problems of the economic plants and animals. He will also be permitted to encourage and aid in the development of a department of entomology for the institute.

Doctor and Mrs. Creighton will sail from New York on June 9. They will return by way of Mexico in September.

Comparative Toxicity of Insecticides Administered in Various Ways to Several Species of Insects[1]

H. MENUSAN, JR.,[2] *Rutgers University, New Brunswick, N. J.*[3]

In order to avoid many of the variables which are inherent in various insecticidal evaluation methods, a blood stream injection method was developed as a basic measure of insecticidal activity. The steps leading up to the development of this method, a review of pertinent literature, and a description of the equipment which was designed specifically for this purpose is taken up in a paper by Heal & Menusan (1948).

In addition to the blood stream test for insecticidal activity, two additional tests have been used, namely a contact test and an oral feeding of measured dosages of insecticides. These three methods can be used to evaluate materials in terms of blood stream activity, contact toxicity, and stomach poisoning action.

EXPERIMENTAL INSECTS.—The adult stage of the American roach, *Periplaneta americana* (L.), was used as the primary test insect. Rigid control of the food and the rearing environment produced roaches whose insecticidal resistance was maintained at a constant high level (Heal 1948). Cockroaches were used that had been adults for at least 2 months but not more than 4 months.

In addition to the American cockroach, four other species of insects were injected with insecticides in the blood stream. These insects were: field collected adults of *Popillia japonica* Newn. and *Anasa tristis* (Deg.); larvae of *Ceratomia catalpae* (Bdvl.); and reared larvae of *Bombyx mori* (L.). For contact toxicity determinations two additional insects were used. These were reared adults of *Oncopeltus faciatus* (Dall.) and *Tenebrio molitor* L.

Insects used were selected, in so far as possible, for uniformity and lack of disease.

The size and weight of individual insects varied considerably, however, even for those which were reared in a controlled environment with an excess of food. For most insects no attempt was made to determine the sex or to keep sex data separately, that is, the tests were run on a mixed population. However, with the American cockroach the data was kept separately for each sex. The following table summarizes the data on the weight of insects.

Table 1.—Weights of various insects.

INSECTS	WEIGHT VARIATION IN GRAMS	AV. WEIGHT OF INDIV. INSECT IN GRAMS
Periplaneta americana:		
Males	.70–1.15	.90
Females	1.00–1.90	1.30
Anasa tristis	.08– .16	.126
Oncopeltus faciatus	.04– .09	.065
Popillia japonica	.07– .14	.096
Tenebrio molitor	.08– .15	.105
Ceratomia catalpae, larvae	1.00–2.30	1.50
Bombyx mori, larvae	.60–1.90	1.20

EXPERIMENTAL METHODS.—All insects were cooled before treatment in an electric ice cream refrigerator. The period of cooling varied from 1.5 to 2 hours, at an average temperature of 28° F. This precooling renders the insects inactive, facilitates handling and prevents undesirable body movement during insecticidal treatment. Overcooling is not desirable, particularly for the cockroach, silkworm and catalpa worm. These three insects were rendered more susceptible to insecticides when exposed for any length of time to temperatures below 25° F. The other insects used could withstand lower temperatures without any appreciable injury.

Overcooling of all insects tended to increase the possibility of bleeding during blood stream injection. For this reason, it is desirable to cool insects just enough to stop body movements during treatment. After cooling, the insects were weighed on a small, rapid, chemical balance and their sex noted when desired.

BLOOD STREAM INJECTION.—The cooled weighed insect, held ventral side up, was

Eastern Branch Program.

[1] The results reported in this paper were obtained at Rutgers University between February 1940 and January 1943, in connection with a research fellowship established by the National Carbon Co. Philip Granett, Harry Haynes, Martin Sherman were especially helpful in performing the experiments and recording the data.

[2] Present address is Division of Agriculture Extension, Pennsylvania State College, State College, Pa.

[3] Journal Series paper of the New Jersey Agricultural Experiment Station, Rutgers University, Department of Entomology.

gently but firmly placed upon a 27 gauge, 0.75 inch, steel *Luer* needle which was directly attached (through a ground glass joint) to a graduated micropipette containing the insecticide. Pressure was then exerted by means of a screw mechanism to force the desired volume of insecticide directly into the blood stream. The volume of insecticide injected was held constant between 0.02 cc. and 0.05 cc. per gram of insect and dosages required obtained by varying the concentration. Large insects, such as the cockroach, silkworm and catalpa worm, were usually injected at the 0.02 cc. per gram rate and all the other insects at the 0.05 cc per gram rate.

The point of injection varied with the different insects. The cockroach and squash bug were injected through the conjunctiva of the third right ventral abdominal segment, between the spiracle and the nearest edge of the body. The needle, pointing anteriorly, was maintained parallel to the integument and inserted for about 0.1 inch. The lepidopterous larvae were injected at the lateral fold at the base of the front left proleg, while the Japanese beetle was injected in the left ventral thorax.

All the insecticides injected in the blood stream of insects were aqueous solutions, emulsions or suspensions. Suspensions and emulsions were passed through a hand homogenizor to render then as uniform as possible before injection. Organic solvents could not be used as the diluent since they were too toxic to insects. When organic solvents were required to facilitate making an aqueous emulsion or suspension of an organic material, acetone or methyl ethyl ketone was used at a maximum of about one-fourth the non-lethal dosage. In these cases sodium oleate was used as the emulsifying agent. The sodium oleate concentration varied directly with the concentration of the insecticide but never exceeded 0.1 per cent soap. This small amount of soap had no effect on the insects, since non-lethal dosages of sodium oleate were from 20 to 50 times this concentration.

CONTACT TOXICITY.—The contact tests were generally made by placing measured volumes of insecticide on the ventral surface of the insect beginning with the mesothorax and covering most of the abdomen. This procedure was a modification of the drop method of Nelson *et al.* (1934). In the case of lepidopterous larvae the insecticide was applied on the dorsal surface of the body. Preliminary tests with the American cockroach did not indicate any difference in toxicity between ventral and dorsal (underneath the wings) insecticidal applications.

The insecticides for contact tests were usually dissolved in ethyl alcohol or acetone before application, although with borax, sodium fluoride, and arsenates, aqueous solutions or suspensions were used. Controls were observed to be certain that the solvent exhibited no contact toxicity. The volume used was 0.02 cc. per gram for the lepidopterous larvae and the coackroach and from 0.05 to 0.07 cc. per gram for the other insects.

ORAL FEEDING OF THE COCKROACH.—A special blunt needle was required for the oral feeding or crop injection of the cockroach. The Luer steel needle used in the blood stream injection was ground down into a smooth blunt point.

The blunt needle was mounted on the micropipette in the manner described for the blood stream test. The needle was inserted into the oral cavity of the cockroach and gently worked into the oesophagus opening.

With the tip of the blunt needle in the oesophagus, the crop injection was started by applying pressure on the aqueous column in the pipette. A properly cooled roach swallows the insecticidal volume forced into its oesophagus in this manner. For crop injection, the roaches required less cooling than for the blood stream injection. Cooling periods of less than half an hour at 28° F. were long enough to prevent violent movements and still have the cockroach active enough to drink the insecticide. The volume of insecticide used for crop injection was maintained at 0.05 cc. per gram except for materials with little toxicity when 0.1 cc. per gram was used.

PROCEDURE AFTER TREATMENT.—All treated insects were placed in groups of 5 to 10, in cheesecloth covered glass jars for daily observations for a minimum period of 6 days and a maximum of 14 days after testing. The insects were placed in three categories: 1, dead; 2, paralyzed (unable to retain their footing and move about); 3, not affected. In the third group many insects were partially affected for periods

of from 1 to 4 days but always recovered from the treatment.

It was found, by repeated observations, that insects paralyzed for 4 days after blood stream injection seldom if ever recovered. Thus, for the injection results reported in this paper all insects paralyzed for 4 days or more were considered dead. With the contact and oral feeding tests the 6-day results appeared to be more consistent than the 4-day results. This was due to some insects affected but not paralyzed. However, by the sixth day these borderline cases could be classified.

The data obtained at the end of 4 to 6 days, depending on the test method, were plotted on graph paper to obtain the dosage-mortality results reported in this paper. Whenever a test was repeated, all results obtained were plotted and a curve fitted to the points obtained experimentally. From 5 to 10 different concentrations of each insecticide were normally used to obtain a toxicity curve, with at least 10 insects used at each concentration. Results obtained were not corrected for natural mortality, since this mortality was less than 0.2 per cent for all the insects used.

All the dosage figures can be modified somewhat by the time and criterion involved. Higher dosage figures would result if the data were taken at the end of 1 day and death was the criterion, instead of death and paralysis at the end of 4 to 6 days.

Some of the insects could go for a long period without food or water. Among these insects were the cockroach, mealworm beetle and squash bug. All other test insects either had to have food or water to avoid mortality due to starvation or water loss. In these cases, the food was changed daily during the period of observation. Where observations had to be carried on for more than 1 week cockroaches were sometimes fed and watered. This was to avoid any possibility of complications from partial starvation.

RESULTS WITH THE AMERICAN COCKROACH.—*Blood Stream.* The blood stream results clearly indicate the large differences in toxicity between the various insecticides tested. Pyrethrins were slightly more effective than rotenone (excluding the derris resins) and these two materials were about six times more toxic to the roach than sodium arsenate. The free alkaloid, nicotine, and sodium fluoride exhibited less than half the toxic action of sodium arsenate, dichloroethyl ether and acid lead arsenate were considerably less effective than nicotine while sodium tetraborate (borax) possessed slight toxicity to the roach.

Nicotine is normally regarded as a quick killing insecticide, although it was observed that injected lethal dosages would paralyze roaches for long periods before death ensued. In the case of sublethal dosages of nicotine, convulsions were noticed as soon as the roach recovered from the chilling received previous to injection. The convulsions were rapid, unconnected movements of the legs, mouth parts, antennae and wings. The convulsion period was followed by paralysis, the duration of which depended on the dosage. In the majority of cases, where recovery took place, the duration of paralysis was less than 24 hours. Occasionally, however, with dosages bordering on the lethal the nicotine paralysis lasted for 3 days before the roaches completely recovered.

Pyrethrins injected into the blood stream of the roach reacted in many ways like nicotine. With the pyrethrins the convulsions were preceded by a period of excitation. The convulsions are slightly more marked with pyrethrins than with nicotine. Recovery, as with nicotine, usually occurred within the first day. Both pyrethrum and nicotine are reported to be nerve poisons, acting through the destruction of the central nervous system. It is possible that their parallelism of toxicity symptoms is due to their similarity of toxic action.

Derris extracts or rotenone when injected into the blood stream of the roach react quite differently from nicotine or pyrethrins. Neither paralysis nor convulsions were clearly evident. Lethal dosages of rotenone resulted in rapid mortality, in a few hours or within the first day, in contrast to the relatively slow mortality of nicotine and pyrethrins. There was some difficulty in suspending pure rotenone crystals in aqueous suspensions. For this reason total extractives containing 25 per cent rotenone were used in all the comparative tests.

The arsenates and fluorides tested reacted similarly in the blood stream of the roach. A dosage at the lethal level might not affect the roach for 1 to 2 days after it was injected. If a large dosage greatly

in excess of the lethal dosage, was injected death resulted in a few hour. Sublethal dosages had no specific observable effects although reductions in normal activity were observed.

Borax, sodium tetraborate, was very slowly toxic. Lethal dosages required 6 days or more to kill the roach. Because of the slow toxicity of borax the results were taken 8 days after injection. With the long test period involved, the roaches were fed and watered as indicated in the test procedure. The addition of food and water did not modify the results. Borax exhibited only 5 per cent as great toxicity as sodium fluoride.

The seven compounds previously discussed vary greatly in their blood stream toxicity but they all show the female roach to be more resistant to insecticides than the male. This difference in insecticidal resistance of the sexes varied with the insecticide; for example, it was relatively a small but significant difference with sodium fluoride, but with lead arsenate and pyrethrins the female exhibited twice as great resistance as the male. The female was not always the more resistant sex as demonstrated by the results obtained with β, β' dichloroethyl ether. In this case the female was only half as resistant as the male. Thus, although the female roach was more resistant to the insecticides in general use the male roach was found to be more resistant to dichloroethyl ether.

In addition to the insecticides discussed above, more than 250 other compounds were injected into the blood stream of the cockroach. A few of these materials are included in table 2 for comparison with the insecticides already mentioned. Only two of these included materials (sodium 4,6-dinitro-o-cresylate and DDT) were highly toxic. Copper sulphate exhibited more toxicity than expected when injected into the blood stream. This toxicity was not due to pH changes since 0.15 mgs. of hydrochloric acid per gram of cockroach was nontoxic.

For many of these materials, only a few points on the toxicity curve were determined and these results are only approximations. Where a limited number of toxicity points were determined, the results for males and females were lumped together.

CONTACT TESTS.—Only cockroaches were used in these experiments. The effectiveness of contact insecticides depends to a great extent on the ability of the material to wet the insect integument. In this investigation ethyl alcohol or acetone was used as solvents for the insecticides in order to avoid wetting difficulties. In the cases of such water soluble materials as sodium arsenate, sodium fluoride and borax the aqueous solutions contained wetting agents or were diluted with equal volumes of alcohol. After the insecticide solution wets the roach the material must penetrate and reach some vital part before toxicity is exhibited.

The reactions of the insect to the insecticides applied by contact were similar to those obtained by injection into the blood stream. Usually at least twice the blood stream dosage was required to obtain equal toxicity on contact, although pyrethrins and rotenone were exceptions to this generality.

Pyrethrins were as toxic by contact as they were by injection. This would indicate that pyrethrins either penetrate the exoskeleton very readily or that pyrethrin toxicity was exerted by contact on the nerve pores of the roach. The evidence obtained tends to support the rapid penetration hypothesis rather than toxicity on nerve endings.

In connection with the contact toxicity of pyrethrins it was noted that lethal and sublethal dosages acted as a purgative on the roach. Another peculiarity of roaches treated with pyrethrins was the tendency for the abdomen to shrink in size. This was particularly marked with paralyzed females, although also present in the males, and occurred long before the death of the insect. This was in marked contrast to the effect of other contact insecticides which either had no effect or tended to cause the abdomen to enlarge (particularly noticeable with nicotine). The contraction of the abdomen appears to be the result of muscular action which may also explain the purging of the pyrethrum treated roaches.

Rotenone which exhibited a blood stream toxicity practically equal to that of the pyrethrins was not toxic when applied by contact. The derris extract appeared to remain more or less unchanged for a week or more on the body of the roach. The nontoxic contact dosages of rotenone were over 150 times the blood stream lethal dosages. It was evident that the rotenone molecule was unable to penetrate the exoskeleton of the roach.

The relatively high contact toxicity of sodium arsenate and sodium fluoride to the cockroach was striking. The arsenate or fluoride did not have to be in aqueous solution to exert contact toxicity since fine suspensions in a water-alcohol mixture (1:1) or powdered sodium arsenate and sodium fluoride applied to the roach resulted in toxicity equal to that of the aqueous solutions. The easy penetration of these water soluble compounds into the waxy covered integument of the roach is rather difficult to harmonize with the idea that penetrability is associated with fat solubility.

Nicotine was not particularly effective as a contact insecticide on the American roach. When the blood stream toxicity dosages and contact dosages were compared it was found that three to six times the blood stream dosages were required to exhibit equal contact toxicity. Most of the other compounds tested, such as pyrethrins, lead arsenate, sodium fluoride, borax and dichloroethyl ether, had smaller ratios of contact-blood stream dosages indicating better penetrability.

Sodium borate exhibited such low contact toxicity that it was impossible to obtain contact toxicity dosages with females. Borax was only slightly toxic in the blood stream and although it exhibited rather high penetrability very high contact dosages would be required for toxicity.

The distinction between dichloroethyl ether and most other contact insecticides so far tried, was that the female roach succumbs before the male. With the other contact insecticides the reverse was true, all the males were usually dead before the females were affected. As a contact insecticide for the female roach dichloroethyl ether was as effective as nicotine. However, nicotine was about four times more toxic to the males than was the ether. These results agree with those obtained on injection into the blood stream of the roach.

The tests with the American cockroach, showed the female to be from 1.6 to 13.3 times more resistant than the male to contact insecticides with an average value of 3.7 for 8 insecticides. This compared with sex differences on injection varying from 1.1 to 2.4 with females averaging 1.6 times the resistance of the males.

ORAL FEEDING.—Various methods for the evaluation of stomach poisoning activity of insecticides have been used. Measured by the number of publications, the leaf-sandwich method is the preferred quantitative method and the general feeding of poisoned food or foliage is the usual qualitative method of measuring the stomach toxicity of materials.

In our tests, only one compound lead arsenate, was as toxic by oral feeding as it was by blood stream injection. In this case the toxicity by crop exceeded that obtained in the blood stream. Solubility factors may account for the greater crop toxicity, as lead arsenate may be more soluble in the gut of the roach than it is in the blood stream. This question can only be answered by data on the comparative pH of the gut and the blood of the American cockroach. Another possible explanation would be that the particles of suspended lead arsenate are segregated by the phagocytic blood cells and thus the lead arsenate blood stream toxicity would be reduced. Some results with small-volume blood stream injection tended to lend support to this theory.

With the exception of colloidal lead arsenate, all the results obtained with the oral feeding are remarkably similar to the toxicity results obtained with the contact tests against roaches. Materials that were highly toxic by the blood stream injection but not toxic on contact were not toxic when injected orally into the crop. In the results presented in table 2, this phenomenon is illustrated by the data obtained with derris extractives. Other materials tested but not reported gave results agreeing with those obtained with derris extractives.

The water soluble sodium fluoride, sodium arsenate and sodium borate were all considerably less effective insecticides when fed than when applied by contact. All these water soluble insecticides appear to penetrate the cuticle of the roach more readily than they are absorbed from the digestive tract of this insect. Even water soluble nicotine is much less effective in the crop than it is when used as a contact insecticide. The low toxicity of crop injected nicotine supports the theory, advanced by some workers, that nicotine insecticidal preparations (including fixed nicotine) kill by contact toxicity and not primarily as stomach poisons.

Pyrethrins, although more effective

than any other material tried in the crop, were only about one-third as effective as when used as a contact insecticide. This means, that for a roach to be killed by stomach action, it would have to take by mouth three times the amount of contact pyrethrins required to cause death. Observations made in the laboratory indicate that the mouth parts of the roach would become paralyzed (by contact action) by the pyrethrins long before the roach could obtain a stomach lethal dose. As a matter of fact, the American roach avoids eating poison or poisoned food. These observations in connection with the experimental results clearly demonstrated that pyrethrins used for the control of roaches must kill entirely by contact action.

Dichloroethyl ether was the only other material (beside lead arsenate) that was more effective in the crop than when applied by contact. Its crop toxicity was considerably lower than the blood stream toxicity. Dichloroethyl ether is rather readily volatilized; the increased toxicity of crop over contact dichloroethyl ether may have been due to the partial loss by vaporization of the latter application. The greater susceptibility of the female roach to dichloroethyl ether, first observed with blood stream injections and also found on contact, was again observed in the oral feeding. No matter how dichloroethyl ether was tested against the roach it required only half the male lethal dosage to incapacitate the female roach.

RESULTS WITH OTHER INSECTS.—From the preceding data with the American cockroach it is evident that the injection method apparently gives a reasonable picture of the toxicity of injected compounds when compared with contact and feeding tests. Insecticidal data based on tests with only one insect has often, in the past, proved to be an unreliable guide when applied to other insects. With the relatively new laboratory methods developed it was highly desirable to include as many different insects as possible in order to test the reliability of these methods.

The equipment for the tests was primarily obtained, or developed, for use in testing the cockroach which averaged more than 1 gram in weight. With slight adjustments, tests could be conducted on insects weighing from 0.1 to 5.0 grams. However, the injector was too large to be highly efficient against insects that averaged much less than 0.1 gram.

BLOOD STREAM RESULTS WITH VARIOUS INSECTS.—A summary of the blood stream toxicity of insecticides to various insects is presented in table 3. The data was limited to those insecticides that have been tried at enough points to obtain a toxicity curve. All results were taken on the fourth day on mixed populations of males and females. The accuracy of the data for each insect depends in great part on the variability of the insect and the number of individuals used to determine the toxicity curve. The Japanese beetle exhibited the greatest variability while the squash bug and the American cockroach reacted most uniformly to insecticidal treatments. We would thus expect the most accurate data with the cockroach and the least dependable with the Japanese beetle.

The insects used for blood stream injection tests exhibited considerable differences in their susceptibility to the insecticides used. The silkworm was so highly susceptibility that work with this insect was discontinued after the tests with nicotine. The catalpa larvae were next in susceptibility to insecticides but exhibited a great deal more resistance than the silkworm. The American cockroach was in general less resistant to the insecticides than the squash bug while the Japanese beetle was the most resistant insect used.

The order of effectiveness of the insecticides tested remained the same regardless of the insect used (in spite of the specific differences in insecticidal susceptibility). Rotenone and pyrethrins, the most effective insecticides in the blood stream, were equally effective against all the insects used, although the pyrethrins appeared to be slightly more effective than rotenone against the cockroach. Sodium arsenate was from three to nine times more toxic than injected nicotine, varying with the different species.

CONTACT TESTS WITH VARIOUS INSECTS.—The contact test results were taken 6 days after treatment, and conducted as described in the early part of this paper.

The silkworm was again highly susceptible to insecticides, when applied by contact. Sufficient silkworms were used to determine the toxicity curve for nicotine. The silkworm was so easy to kill that it was of little value as a test insect. The

Table 2.—The comparative toxicity of insecticides when tested against the American cockroach in various ways. The dosage given in milligrams of insecticide per gram of cockroach.

Insecticide	No. Used	Injection in Blood 0%	50%	100%
Nicotine (free alkaloid)	68M	.03	.08	.14
	92F	.08	.12	.20
Pyrethrins (Pyrethrins I+II)	65M	.001	.003	.006
	64F	.005	.008	.011
Derris, Rotenone dose (T.E. 4×rotenone)	189M	.003	.005	.009
	139F	.005	.008	.013
Sodium arsenate Na_2HAsO_4 & $7H_2O$	159M	.023	.030	.045
	162F	.035	.050	.070
Acid lead arsenate $PbHAsO_4$ (colloidal)	42M	.20	.30	.75
	47F	.30	.75	1.40
Sodium fluoride NaF	24M	.08	.12	.15
	24F	.10	.14	.17
Sodium tetraborate $Na_2B_4O_7$ & $10H_2O$	35M	1.8	2.1	2.4
	35F	1.8	2.6	3.6
ββ′ Dichloroethyl ether	66M	.38	.55	.80
	66F	.18	.25	.40
Azobenzene	45M	.32	.43	.57
	45F	.50	.62	.82
Sodium 4,6-dinitro-o-cresylate	43M	.007	.014	.021
	42F	.020	.028	.050
50% β-Butoxy β′thiocyanodiethyl ether[1]	32M	.10	.15	.20
	32F	.12	.20	.40
Terpinylthiocyano acetate[2]	24M+F	.20	.30	.45
Copper sulphate $CuSO_4$ & $5H_2O$	60M+F	.01	.05	.09
Lorol thiocyanate (60% lauryl & 93% total thiocyanates, mixed)	48M+F	.4	.9	1.5
Wettable sulphur (micronized)	40M+F	.5	.9	1.6
DDT (Dichloro-diphenyl-trichloroethane)	104M	.002	.008	.02
	104F	.01	.02	.04
Controls				
Water	79MF+	100.+nontoxic		
Ethyl alcohol	115M+F	5.6	10.	17.
Acetone	20M+F	6.+nontoxic		
Sodium oleate	96M+F	1.0	2.0	3.0
Aliphatic diglycerides[3]	82M+F	17.	25.±	
Ethylene glycol-laurate (mainly, diethylene, glycol dilaurate)	56M+F	25.	32.	50.±

Insecticide	No. Used	By Contact 0%	50%	100%	No. Used	Oral Feeding 0%	50%	100%
Nicotine (free alkaloid)	86M	.08	.14	.50	52M	.90	2.4	4.0
	86F	.65	.80	1.3	54F	2.0	3.1	5.2
Pyrethrins (Pyrethrins I+II)	70M	.002	.004	.006	55M	.008	.014	.020
	75F	.006	.009	.012	53F	.018	.029	.040
Derris, Rotenone dose (T.E. 4×rotenone)	33M	2.+nontoxic			55M	1.+nontoxic		
	32F	2.+nontoxic			53F	1.+nontoxic		
Sodium arsenate Na_2HAsO_4 & $7H_2O$	67M	.03	.10	.30	54M	.08	.25	.60
	72F	.15	.50	1.30	58F	.60	2.0	6.0
Acid lead arsenate $PbHAsO_4$ (colloidal)	67M	.20	.50	1.30	65M	.05	.15	.60
	63F	.40	1.2	2.1	69F	.15	.40	1.0
Sodium fluoride NaF	60M	.16	.25	.35	79M	.10	.30	1.3
	56F	.20	.50	.85	96F	.20	1.0	3.5
Sodium tetraborate $Na_2B_4O_7$ & $10H_2O$	58M	.9	2.5	4.0	44M	1.4	4.5	12.0
	50F	2.5+nontoxic			42F	2.0	8.0	16.0
ββ′Dichloroethyl ether	52M	.75	1.4	2.1	43M	.50	.75	1.0
	47F	.45	.80	1.2	43F	.20	.35	.50
Azobenzene	36M	.50	.80	1.1		not tested		
	36F	.85	1.3	2.0				
Sodium 4,6-dinitro-o-cresylate	40M	.015	.020	.030		not tested		
	63F	.18	.23	.40				
50% β-Butoxy β′thiocyanodiethyl ether[1]	65M	.36	.66	1.36		not tested		
	65F	.56	1.26	2.3				
Terpinylthiocyano acetate[2]	15M	3.5	4.8	6.0±		not tested		
	15F	7.+nontoxic						
Copper sulphate $CuSO_4$ & $5H_2O$	13MF+	.3	1.0	3.±		not tested		
Lorol thiocyanate (60% lauryl & 93% total thiocyanates, mixed)		not tested				not tested		
Wettable sulphur (micronized)		not tested				not tested		
DDT (Dichloro-diphenyl-trichloroethane)		not tested				not tested		
Controls								
	60M+F	150.+nontoxic			44M+F	150.+nontoxic		
Ethyl alcohol	52M+F	40.+nontoxic			20M+F	25.+nontoxic		
Acetone	41M+F	40.+nontoxic			64M+F	20.	70.	140.±
Sodium oleate		not tested				not tested		
Aliphatic diglycerides[3]		not tested				not tested		
Ethylene glycol-laurate (mainly, diethylene, glycol dilaurate)		not tested				not tested		

Note: Results obtained after 4 days for blood injection and after 6 days for contact and oral feeding; except for borax, whose slow toxicity, required from 8 to 10 days to exhibit maximum toxicity.

[1] *Lethane 384.* [2] *Thanite.* [3] *Triton 1956*, commercial.

catalpa worm, which possessed low resistance to insecticides, required over 20 times the silkworm lethal dosage before it became incapacitated. Rotenone and pyrethrins were so toxic to silkworms that no attempt was made to determine toxicity curves for these materials.

β′ thiocyano-diethyl ether[1] but differ in their reaction towards the dinitro compound tested. Although not included in table 4, 0.5 millgram of sodium 4,6-dinitro-o-cresylate per gram of bug was not toxic to the squash bug but this dosage would kill the cockroach.

Table 3.—Toxicity of various insecticides when injected into the blood stream of different insects. The dosage given in milligrams of poison per gram of insect.

Insecticide and Insect	No. of Insects Used	Nontoxic Dose	Median-Lethal Dose	Lethal Dose (Down or Dead)
Nicotine (Free alkaloid)				
Periplaneta americana	160	.03	.10	.20
Anasa tristis	51	.05	.20	.35
Popillia japonica	160	.15	.40	.90
Ceratomiá catalpae, larvae	82	.04	.08	.15
Bombyx mori, larvae	28	.0005	.003	.007
Pyrethrins (P I+II)				
Periplaneta americana	129	.001	.006	.011
Anasa tristis	25	.004	.010	.025
Popillia japonica	229	.01	.04	.11
Ceratomia catalpae, larvae	32	.001	.004	.006
Derris resins (Rotenone dosage given=25% dosage of T.E.)				
Periplaneta americana	328	.003	.007	.013
Anasa tristis	25	.004	.010	.025
Popillia japonica	229	.01	.04	.11
Ceratomia catalpae, larvae	32	.001	.004	.006
Sodium arsenate ($Na_2HAsO_4 \cdot 7H_2O$)				
Periplaneta americana	321	.023	.045	.07
Anasa tristis	30	.01	.02	.04
Popillia japonica	130	.02	.05	.10
Ceratomia catalpae, larvae	30	.01	.02	.03
50% β-Butoxy β′thiocyano diethyl ether[1] commercial, dosage given				
Periplaneta americana	64	.10	.17	.40
Popillia japonica	48	.10	.30	.09

[1] *Lethane 384.*

The milkweek bug was easier to kill by contact insecticides than the cockroach. Rotenone was considerably more toxic to this insect than were pyrethrins. Some preliminary experiments with milkweed bugs and sodium 4,6-dinitro-o-cresylate indicated that the females were highly resistant to this insecticide. Sex differences of the cockroach to this compound were greater than 10-fold, as shown by the results in table 2.

The squash bug generally reacted about the same as the cockroach when used as a test insect for contact insecticides. The squash bug and cockroach integument are alike in their lack of resistance to penetration of pyrethrins, nicotine and β-butoxy

The two beetles used were more resistant to contact insecticides than were any of the other insects. *Tenebrio molitor* equalled the Japanese beetle or was more resistant than it to the insecticides used.

Excluding the milkweed bug and meal worm beetle, since they were not used in injection tests, we can compare the relative resistance of the insects to injection and contact tests. In descending order of resistance to injected insecticides: Japanese beetle, squash bug, cockroach, catalpa wormand silk worm. For contact insecticides the order of the three most resistant insects is variable but catalpa worm and silkworm are in the same order

[1] *Lethane 384.*

as observed in the blood stream injection. The variation in order of these resistant insects to different contact insecticides seems to be due entirely to variations in the ability of the insecticides to penetrate the integument of the specific insect.

much less effective when used as a contact insecticide.

The accuracy of all the contact tests could be greatly increased by testing males and females separately as was done with the cockroach. In general, depending

Table 4.—The contact toxicity of insecticides when applied to different species of insects. Dosages in milligrams of poison per gram of insect.

Insecticide and Insect	No. of Insects Used	Nontoxic Dose	Median-Lethal Dose	Lethal Dose (Down or Dead)
Nicotine (Free alkaloid)				
Periplaneta americana	172	.08	.65	1.30
Anasa tristis	50	.15	.35	1.25
Oncopeltus faciatus	154	.09	.19	.45
Popillia japonica	25	.30	.65	1.00
Tenebrio molitor	123	2.00	3.20	4.40
Ceratomia catalpae, larvae	32	.04	.10	.20
Bombyx mori, larvae	60	.0006	.004	.008
Pyrethrins (P I+II)				
Periplaneta americana	145	.002	.0065	.012
Anasa tristis	58	.002	.007	.026
Oncopeltus faciatus	152	.003	.008	.028
Popillia japonica	107	.01	.04	.13
Tenebrio molitor	68	.025	.035	.10
Ceratomia catalpae, larvae	32	.0007	.002	.006
Bombyx mori, larvae	20			below .0004
Derris resins (Rotenone dosage given 25% dosage of T.E.)				
Periplaneta americana	65	2.0+ above		
Anasa tristis	36	2.6+ above		
Oncopeltus faciatus	165	.0012	.0025	.006
Popillia japonica	250	.005	.025	.06
Tenebrio molitor	116	.005	.019	.075
Ceratomia catalpae, larvae	54	.001	.002	.005
Bombyx mori, larvae	42			below .0007
Sodium arsenate (Na_2HAsO_4 $7H_2O$)				
Periplaneta americana	139	.03	.25	1.30
Popillia japonica	51	.4	.85	1.70
50% β-Butoxy β'thiocyano diethyl ether[1] dosage given				
Periplaneta americana	130	.36	.96	2.3
Oncopeltus faciatus	76	.12	.40	.75
Popillia japonica	145	.35	.80	1.70
Tenebrio molitor	100	.40	.85	1.60

[1] *Lethane 384.*

Pyrethrin was the only insecticide that was highly toxic to all insects on contact, about equal to its blood stream toxicity. These results demonstrate the ability of pyrethrins to penetrate. Rotenone, when able to penetrate, was also highly toxic by contact. It was more toxic in this way than pyrethrins against beetles, milkweed bug and catalpa worm. Nicotine varied in its contact toxicity, in some cases (Japanese beetle, catalpa worm and silkworm) it was equally toxic by contact or injection, in all others it appears to be

on insecticide and insect used, there appear to be greater sex differences in resistance to contact insecticides than there were to injected insecticides.

Discussion.—The relative order of toxicity of insecticides injected into the blood stream was the same as that generally observed in the practical control of insects. That is, insecticides usually considered most effective in the field were most toxic in the laboratory. From the results reported in this paper, it is evident that the blood stream injection evaluated

some kind of basic toxicity of the materials used. Since insecticidal dosages required for toxicity by blood stream injection were less than those required by the other methods of testing, we can consider the injection method to give us the maximum potential insecticidal activity of the material under test.

Although a number of investigators have used the blood stream injection method for determining the toxicity of some insecticides, few have used either the insects or insecticides reported in this paper. Campbell (1932) and Hansberry *et al.* (1940) reported MLD of injected nicotine to be about 0.002 milligram per gram of silkworm while McIndoo (1937) reported the lethal doasge of injected nicotine 1.44 milligrams per gram against the same insect. Our results with nicotine injected into silkworms was a MLD of 0.003 milligram and a LD of 0.007 milligram per gram. It is impossible to explain how McIndoo obtained lethal dosages about 200 times larger than those reported by other investigators.

There is one report on the toxicity of nicotine injected into the American cockroach by Richardson & Ellisor (1940). These investigators obtained non-lethal and median lethal dosages in close agreement with results reported in this paper, although their lethal dosages were more than twice those reported in this paper.

The insecticidal activity of various compounds by contact was usually much less than their toxicity in the blood stream. This lessened toxicity when applied by contact appeared to be due primarily to lack of penetrating ability of the various insecticides into the insect exoskeleton. From several hundred materials tested, both by contact and injection against the cockroach of which 13 are summarized in this paper, pyrethrum was the only one whose contact toxicity approximated the injection toxicity. Some materials could not penetrate the insect integument regardless of the amount or the way they were applied by contact. This lack of ability to penetrate is illustrated by rotenone against the American cockroach and the squash bug, although many other compounds gave similar results.

The permeability of insect cuticle to insecticides has been studied by many investigators. In a review of insect physiology and toxicology (Hoskins 1940) it is reported that substances such as nicotine, cyanide and pyrethrum, which are soluble in fat or fat solvents, more readily penetrate the insect integument than materials insoluble in fat solvents, such as arsenates and fluorides. On the other hand, many investigators working with water soluble arsenates and fluorides (O'Kane & Glover 1935, 1936; Hockenyos, 1933, 1939; Sweetman & Laudani, 1942) appear to suggest that these materials penetrate the cockroach integument as aqueous solutions. It has been pointed out by Hurst (1940) that the cuticle of insects possesses a high degree of asymmetry. This asymmetry affects the permeability of the whole cuticle and is modified in different insects or in different parts of the same insect by the distribution of various substances in the cuticle.

The fundamental question of how insecticides penetrate the integument of insects was not studied during this investigation. However, relative values of the penetrating ability of a given insecticide might be obtained from the ratio of contact dosage to injection dosage for equal toxicity given in tables 2, 3 and 4. A ratio of 1.0 would indicate complete penetration and the degrees of decreasing penetration would be indicated by larger ratios. Pyrethrum and lead arsenate exhibited the highest penetrating ability of the insecticides tested against the American cockroach. Other insecticides sodium tetraborate, azobenzene and sodium 4,6-dinitro-ortho-cresylate) readily penetrated the male roach integument but did not exhibit as high a penetrating ability against female cockroaches. All insecticides, in general, were able to penetrate the male integument more readily than female integument of cockroaches.

In a number of tests with pyrethrum and isobutyl undecylenamide, a pyrethrum synergist, the toxicity of the mixture to cockroaches was approximately double that of equal concentrations of pyrethrum without the synergist. This increase in toxicity was obtained in both the injection and contact tests indicating that the synergistic action was not due to differences in penetrability.

Oral administration of insecticides normally resulted in less effective insecticidal action than when the same material was applied by contact. The only exceptions to this generalization were obtained with

lead arsenate and dichloroethyl ether. The probable explanation for these exceptions was discussed previously in this paper. The general reduced toxicity of insecticides when fed was probably due to dilution and adsorption of the insecticide by food present in the gut of cockroaches.

There appears to be a qualitative if not quantitative similarity in the penetrating ability of various insecticides through the walls of the digestive tract and the integument of the American cockroach. Thus, rotenone which did not penetrate the integument of the cockroach was not absorbed when fed orally. Materials which readily penetrated the cockroach integument, such as pyrethrum, lead arsenate and dichloroethyl ether, were also readily absorbed from the gut. Other compounds like nicotine, sodium arsenate and sodium fluoride which did not penetrate the integument as readily as the compounds mentioned above were less readily absorbed from the digestive tract.

From these results, and others not reported in this paper, it would appear that any compound which kills an insect by contact action would also be effective as a stomach poison when eaten by the same species of insect. Thus, it is possible that the contact toxicity of an insecticide in conjunction with data on its stability on plants would evaluate its probable stomach poisoning effectiveness. A study of the results reported in this paper clearly show that the materials commonly used to control cockroaches act primarily as contact insecticides and not as stomach poisons as is usually assumed. For example, pyrethrum required three times the contact dosage to kill when fed. Sodium fluoride toxic dosages when fed were two to four times the dosages needed to kill by contact.

The application of predetermined dosages to each individual insect increased the accuracy of the evaluation of insecticidal efficiency. This, in conjunction with the use of insects whose resistance to insecticides remained relatively constant, greatly reduced the number required to be treated for dependable results. In the past, much data has been accumulated which generally indicated that from 30 to 100 insects were needed for each dosage point. These limits were determined by statistical methods based on sampling errors of mixed populations, and also by numerous experimental observations. In our investigation it was found that as few as 10 insects (5 of each sex) for each dosage point was sufficient for the approximation of toxicity curves.

To obtain accuracy with these smaller numbers certain precautions must be taken. The insects must be reared under constant (controlled) environmental conditions, so that their insecticidal resistance remains constant. The age of insects used for testing must be the same within narrow limits. The dosage of insecticide must be adjusted to each individual insect according to its weight, and finally the insects must be segregated according to sex. Sex differences in resistance to insecticides are so great that a population of males and females cannot be considered homogenous.

The greater dosage of insecticide required to affect the female of the species has been observed by many investigators. Simanton & Miller (1937) and Sullivan *et al.* (1938) reported female flies more resistant than males to pyrethrum sprays. McGovran *et al.* (1941) found female American cockroaches approximately twice as resistant as the male to pyrethrum sprays. In a recent review of sex differences in morbidity and mortality, Ciocco (1940) points out the many examples, in insects and other animals, where the female appears more resistant than the male.

The difference in susceptilibity to insecticides between male and female cockroaches varied greatly depending on the insecticide and the method of testing. There was less sex difference in resistance to an insecticide when the material was injected into the blood stream than when the same material was fed or tested for contact toxicity. Practically all materials tested showed the male to be less resistant than the female, with the exception of dichloroethyl ether where the reverse was true and the male exhibited twice the resistance of the female. There is no explanation at present for this reversal in sex resistance with this compound.

Similar differences in insecticidal resistance between the sexes were observed with all the adult insects used. Data on the sex susceptibility of these other insects was not tabulated since the test insects were not segregated according to sex.

SUMMARY.—Insecticidal activity of various materials was tested against the American cockroach in three ways: by blood stream injection, by contact, and by oral feeding. These three methods evaluated materials in terms of blood stream toxicity, contact toxicity and stomach poison activity. The materials tested, generally required smaller dosages to be toxic when injected into the blood stream than when used as contact or stomach poisons.

Contact toxicity, against the cockroach, usually required about twice the dosage of insecticide needed for blood stream toxicity. Pyrethrum was the only material that was equally toxic by contact or by injection. There was a striking similarity in the reaction of the cockroach to contact and stomach poisons. The materials not toxic by contact were not toxic fed and those toxic by contact were effective insecticides when fed. Toxic dosages of insecticides by feeding were usually considerably higher than when the same materials were applied by contact.

Sex differences in resistance to insecticides were exhibited in varying degree by the cockroach, depending on the insecticide used and the method of testing. With the exception of dichloroethyl ether, the female was always more resistant than the male. Sex difference was smallest in the blood stream test where the female averaged 1.6 times the resistance of the male. With both contact and oral feeding tests the female averaged three to four times the resistance of the male.

The application of predetermined dosages to each individual insect increased the accuracy of the evaluation of insecticidal efficiency. Due to large sex differences it is important either to test the sexes separately or, in case of mixed populations to be sure that both sexes are evenly distributed.

Other insects used for blood stream and contact tests, varied greatly in their susceptibility to insecticides. In order of increasing resistance to insecticides they were as follows: silkworm, catalpa worm, cockroach, squash bug and Japanese beetle. The milkweed bug used in contact tests appeared to be more susceptible to insecticides than the cockroach while the meal worm beetle exhibited as high a degree of resistance as the Japanese beetle.

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Sulfa Drugs for American Foul Brood of Honeybees: Third Report

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Experiments with sulfa and other drugs fed to honeybees through the medium of a sugar and water mixture to control American foul brood of honeybees have been carried through the three seasons of 1945, 1946 and 1947. The first season's work was reported by Johnson & Stadel (1945); the results of the second season's work by Johnson (1947) and the combined results of the three seasons are herein reported.

A total of 24 hives has been used in the experiments. If the results of the treatment given an individual hive were negative and the colony remained in such a condition that it could be subjected to other treatment, such was done. All hives remained in the experimental apiary in their original positions regardless of the results of the treatments in adjacent hives. No hive was nearer than 5 feet from the neighboring hives. There have been only four cases to date where colonies became so weakened that fumigation with cyanide was necessary to prevent robbing. These four were, in each case, removed from the experimental apiary until the time of recolonization and the resumption of treatment. Each was or will be returned to its original position. One colony was winter-killed and the hive later recolonized. Most of the diseased hive were obtained from the field by the apiary inspectors, usually composed of two or more sections, and used as received. The equipment of each hive has been numbered and kept intact. It has been removed or returned to the original hive as needed. In every case introduction of new queens, package bees or additional equipment was avoided unless absolutely necessary. A few hives have proven to be colonized with poor queens and relatively non-producing bees. Others are strong and active being good producers. Nothing was done to enhance the recovery of the colonies by manipulation or the introduction or exchange of equipment or bees. The main outside introductions were the addition of new supers and frames to producing colonies and package bees to non-populated or special test hives. Only one colony succeeded in swarming, as it developed faster than expected. Supercedure has taken place in practically all the colonies. It has not been alarming.

The procedure in feeding the drugs has been approximately the same in every case. The drugs were usually fed at the rate of 0.5 gram to 1 gallon of a sugar and water mixture made 1 to 1 by volume. The solution was fed in 5-pound honey pails having perforated tops and placed in an inverted position over the hole of the inner cover as a gravity feeder and protected by an empty super and top cover, or in a *Boardman* feeder. The *Boardman* feeders were used usually during a honey flow and when there were extra supers on the hive. In many cases both methods were used at the same time on a hive.

Originally, in 1945, eight hives were used in the experiments. Hives 1, 2, 3 and 4 received sulfathiazole, 0.5 gram per gallon of sugar and water fed in gravity feeders and sulfathiazole at the rate of 0.5 gram per gallon of water in Boardman feeders. Hives 5 and 6 received just the sulfathiazole-sugar-water mixture. The six colonies, Hives 1 to 6 inclusive, receiving the sulfathiazole-sugar-water mixture eliminated all visual evidence of the disease before the fall season ended. Hive 7 was sprayed at weekly intervals with the sulfathiazole-water mixture. This colony, although considerably improved, failed to eliminate the disease. Hive 8 served as an untreated control. The control hive was gradually depleted by the disease and it was necessary to fumigate it with cyanide before the end of the season.

In 1946, Hives 1, 5 and 6 passed through the season without any visual evidence of the disease. Hive 2 had a relapse and the first two diseased cells were observed on May 31, 1946. The colony did not receive treatment during that year and the disease increased as the season progressed. However, the colony produced surplus honey and was strong enough to pass through the winter of 1946–47.

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[1] Assisted by Roy Stadel, Apiary Inspector, Connecticut Agr. Expt. Station.

Hive 3 had an occasional relapse during 1946, and a total of 11 diseased cells were observed up to mid-season. However, no treatment was given this colony during the season and no further evidence of the disease was seen.

A few scales, covered by honey stores, were observed in Hive 4 on April 30. It was evident that sufficient stores containing sulfathiazole were available to offset the spores from these scales and no infection was observed during 1946.

Hive 7, the sprayed hive, failed to clean up all visual signs of the disease in 1945, received no treatment in 1946 and the disease increased as the season progressed. The colony produced surplus honey and successfully passed through the winter of 1946–47.

In the fall of 1945, a badly infected hive had been secured from the field and installed as Hive 8, replacing the original Hive 8 which had been fumigated and removed from the apiary. Treatment with the sulfathiazole-sugar-water mixture was begun that fall and resumed in the spring of 1946. Hive 9 was obtained in the spring of 1946 and treatment with the same material begun. In late May of 1946, three hives consisting of the untreated, fumigated control hive of 1945 and two recently acquired non-populated diseased hives were colonized with package bees and laying queens. These hives were assigned numbers 14, 15 and 16. They were treated with sulfathiazole at the rate of 0.5, 1.0 and 2.0 grams respectively per gallon of sugar and water solution. These five colonies of bees eliminated all visual evidence of disease in 1946.

In 1946, two hives were treated with sulfapyridine at the rate of 0.5 gram to 1 gallon of sugar and water solution, but failed to show improvement and the treatment was discontinued. Treatments with sodium sulfathiazole and sulfaguanidine also were begun in 1946.

Another diseased colony, serving as a control and fed just sugar and water, (1 to 1 by volume) was added to the experimental apiary in mid-July, 1946. This colony was fed 3.5 pints of the sugar-water mixture at weekly intervals throughout the season. Although, as the season progressed the colony maintained its strength, the disease persisted. This colony passed through the winter of 1946–47 successfully.

All colonies, excepting that in hive 9, passed through the winters of 1946–47 successfully. Hive 9 was recolonized with package bees and a laying queen on May 16, 1947. During the season of 1947, Hives 1, 3, 4, 5, 6, 8, 9, 14, 15, and 16, excepting Hive 9 in which one single cell was found diseased on two separate inspections in July, were free of all visual evidence of disease during the season of 1947. Of these 10 hives, receiving sulfathiazole as the treatment, five, namely 1, 3, 4, 5, and 6 were originally treated in 1945 and the remaining five in 1946. As none of these hives received any additional extended fall or spring treatments after the original medications with sulfathiazole, the data show that five out of six hives remained free of disease for 2 full years and 10 out of 11 passed through 1 year without a definite recurrence of the disease.

In 1947, Hives 12 and 13, treated in 1946 with sulfapyridine and penicillin respectively, without any perceptible improvement, were fed sulfadiazine at the rate of 0.5 gram to 1 gallon of sugar and water, beginning in mid-April and discontinued in mid-September. No visual evidence of disease was observed in either of the hives on or after July 3. Hives 2 and 7 were treated in the season of 1947 with the sulfathiazole-sugar-water mixture. The treatment of these two hives was begun on April 1, 1947, and terminated on August 25. This was a resumption of the same method of treatment for Hive 2, originally treated in 1945, found reinfected in 1946 and in which the disease was allowed to build up again without scales appearing in the hive. All evidence of disease in this hive disappeared by June 16. Hive 7 did not respond too successfully to the sulfathiazole-water spray in 1945 and the disease was allowed to build up in 1946 for definite treatment with the sulfathiazole-sugar-water mixture in 1947. No visual evidence of disease was observed after July 24, 1947.

Hive 10, which was recolonized with a 3-pound package of bees and a laying queen on May 16, 1947, was treated with 0.5 gram sulfathiazole per gallon of sugar and water mixture. However, the recolonization was not successful and the colony was fumigated with cyanide in late June. Hive 11 received additional treatments of sodium sulfathiazole in 1947. The treat-

ment of this colony with sodium sulfathiazole originally began on August 5, 1946, and had passed the winter of 1946–47 with the sulfa in its stores. The hive was free of all visual evidence of disease on July 1, 1947, and the treatment was discontinued on August 25.

Hive 12, originally treated in 1946 with sulfapyridine, and Hive 13, with penicillin, were treated in 1947 with sulfadiazine at the rate of 0.5 gram to 1 gallon of the sugar-water mixture. The treatments were begun in mid-April and continued until August 25. There was no visual evidence of disease in either of these hives on or after July 3.

Hive 17 was introduced into the experimental apiary in 1946 as a diseased control. Three and one-half pints of the sugar and water mixture were fed 22 times at approximately weekly intervals to this colony throughout the season of 1947. The feeding stimulated brood rearing, but the disease persisted, as indicated by the presence of dead larvae and scales. This colony began to decrease in population during the last part of the 1947 season and scales were becoming increasingly more numerous. The colony should survive the winter.

The treatment of the colonies in Hives 18 and 19 with sulfaguanidine was begun on August 6, 1946, and continued until October 29 of that year. It was resumed in 1947 on April 1 and continued until early October. Hive 20, treated with X-ray in 1946 and later again in the same season with sulfapyridine, failed to respond to these treatments, yet was strong enough to survive the winter of 1946–47. This colony was treated with sulfaguanidine in 1947. Each of these three colonies was fed 20 or more times, the minimum feeding consisting of 3.5 pints of a 0.5 gram sulfaguanidine-sugar-water mixture. As these colonies were not free of visual evidence of the disease until September 24, 1947, it was evident that the drug, although effective, is not as efficient as sulfathiazole, sulfadiazine or sodium sulfathiazole.

Hive 21, a strong, non-diseased colony was introduced into the experimental apiary in the spring of 1947 as a non-diseased, non-treated control. This colony continued to flourish and was free of all evidence of disease in October of the present year.

Hives 22, 23, and 24 consisting of new brood chambers and frames with foundations were added to the experimental apiary and colonized with 3-pound package bees and laying queens on May 17, 1947. These colonies were fed sugar and water and developed until there were at least six frames of brood and bees. The three hives were used in one experiment, with Hive 24 serving as a non-diseased control. Hives 22 and 23 were each fed 8 cc. of treated spore material in 3.5 pints of sugar and water mixed 1 to 1 by volume. The treated spore material was prepared for the experiment by placing 100 scales of the larvae, which had died from American foul brood disease, in a flask containing 50 cc. of water and glass beads and agitated for 17 hours and 45 minutes on a shaker machine. Units of this mixture[1] in the amount of 10 cc. each were placed in a copper-foil container, having walls 0.003 inch in thickness, and subjected to the impact of the vibrations from an ultra sonic machine. The acoustical power delivered to the mixture inside the container was from 100 to 150 watts. Hive 22 was fed material which had received treatment for a total of 4 minutes, exposed in four equal installments of one minute each to prevent overheating. Hive 23 was fed material which had received treatment for a total of 3 minutes, exposed in six equal installments of 30 seconds each. The two hives were fed the mixtures on July 7, and on July 24 numerous diseased larvae were found in both hives.

During the interval of July 24 and August 14 the disease continued to increase in Hives 22 and 23, and on the latter date Hive 23 was sprayed with 8 ounces of ethyl alcohol containing 1 gram of sodium sulfathiazole. At this time the colony contained seven frames of capped and uncapped brood and eggs from which the adult bees were shaken before spraying. On August 25, very little uncapped brood was present, scales were very numerous and there were many young larvae lying dead in the bottoms of the cells apparently killed by the treatment. A few eggs were present, but the number of living larvae was very small. As the colony had been depleted by the treatment and the nectar flow was poor, sugar

[1] The ultra sonic treatment was made by Dr. R. H. Wallace of the University of Connecticut, who collaborated in this experiment.

and water containing 0.5 gram sodium sulfathiazole was fed to the colony. Five feedings, totalling 20 pints, were given in the next few weeks. However, on October 3, 1947, this colony was too weak to survive the winter so it was fumigated with cyanide. Colony 22 which, though diseased had not been sprayed with the alcohol sodium sulfathiazole mixture and which had been fed just sugar and water, maintained its strength and probably will survive the winter. The untreated, a manner practically identical to that when sulfathiazole is used.

3. That sulfaguanidine, although promising as a control drug, is much slower in action than the preceeding drugs.

4. That when sulfathiazole, sodium sulfathiazole or sulfadiazine is fed to a diseased colony in a multiple-sectioned hive, the treatment must be prolonged to offset any lurking spores contained in hidden scales or old honey stores.

5. That the population of a diseased

Table 1.—Statistics of treatment with various sulfa drugs for American foul brood disease of honeybees and the results obtained in 1947.

Hive No.	Material Used	Date of First Treatment	Date of Last Treatment	No. of Treatments	Total Amount of Material, Pints	Total Drug Fed, Gms.	Free of Disease	Drug Found in Surplus Honey
1	Sulfathiazole[4]	1945	1945	[1]	—	—	10- 8-45	—
2	Sulfathiazole	[2] 6- 6-45 4- 1-47	10-28-45 8-18-47	17 18	49 100	3.968[1] 6.25	6-16-47	57 p.p.m.
3	Sulfathiazole	1945	1945	[1]	—	—	10-22-45	
4	Sulfathiazole	1945	1945	[1]	—	—	10-22-45	
5	Sulfathiazole	1945	1945	[1]	—	—	8-13-45	
6	Sulfathiazole	1945	1945	[1]	—	—	8-13-45	
7	Sulfathiazole	[2] 6- 3-45 4- 1-47	9-24-45 8-18-47	12 16	[1] 87.5	2.06 5.47	7-24-47	60 p.p.m.
8	Sulfathiazole	1945 & 46	1946	[3]	—	—	9- 5-46	
9	Sulfathiazole	1946	1946	[3]	—	—	9-17-46	
10	Sodium sulfathiazole	5-27-47	6-23-47	4	14.5	0.9	Cyanided 8-17-46	
11	Sodium sulfathiazole	8- 3-46 4- 1-47	10-29-46 8-18-47	24	88.5	5.53	5-16-47	65 p.p.m.
12	Sulfadiazine	4-26-47	8-18-47	14	68	4.25	7- 3-47	45 p.p.m.
13	Sulfadiazine	4-17-47	8-18-47	14	66	4.12	7- 3-47	
14	Sulfathiazole	1946	1946	—	—	—	8- 5-46	
15	Sulfathiazole (1 gm. per gal.)	1946	1946	—	—	—	6-24-46	
16	Sulfathiazole (2 gms. per gal.)	1946	1946	—	—	—	7-16-46	
17	Sugar and water (Diseased control)	1946	10- 3-47	21	73	None	Still infected	trace or none
18	Sulfaguanidine	8- 6-46 4- 1-47	10-15-46 10- 3-47	29	114	7.12	9-24-47	
19	Sulfaguanidine	8- 6-46 4- 1-47	10-15-46 10- 3-47	28	110.5	6.90	9-24-47	
20	Sulfaguanidine	4- 1-47	10- 3-47	21	100	6.25	9-24-47	29 p.p.m.
21	None (No disease control)	—	—	—	None	None	None	
22	None (Diseased control)	—	—	—	None	None	Infected	
23	Sodium sulfathiazole	8-25-47	9-23-47	5	20	—	Cyanided 10- 3-47	
24	None (No disease control)	—	—	—	None	None	None	

[1] See report of 1945 for details.
[2] Not treated in 1946.
[3] See report of 1946 for details.
[4] All colonies fed 0.5 gm. of drug per gallon of sugar and water unless otherwise noted.

non-diseased Hive 24, was still free of disease and flourishing.

The statistics of the treatments and the results obtained during these experiments are given in table 1.

CONCLUSIONS.—1. When sulfathiazole at the rate of 0.5 gm. per gallon of sugar and water mixture is fed to colonies of bees infected with American foul brood, the disease may be eliminated for a period of at least 2 years subsequent to the treatment.

2. That when sulfadiazine or sodium sulfathiazole are fed in the same amounts, the treated colonies react to these drugs in hive, the number of diseased frames and the amount of old stores present are factors influencing the length of treatment.

6. That all cells in all the frames must be cleaned and used by the bees during the period of treatment.

7. That the sulfa drugs will be deposited in the surplus honey if treatments are made during the period the colony is gathering such stores.

8. That if colonies respond rapidly to the treatment, there is little or no danger of robbing.

9. That a diseased colony may be stimulated in brood rearing by feeding it a

sugar water solution to aid in maintaining the hive population but the disease will persist.

10. That the viability of spores treated with acoustical power of 100 to 150 watts delivered by an ultra sonic machine was not materially affected.

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Control of Soil Insects

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Comparative toxicity tests with DDT and some other recently developed insecticides such as chlorinated camphene[1], benzene hexachloride, chlordan and parathion useful against soil inhabiting insects such as the Japanese beetle, various species of ants and chinch bug were conducted at the Connecticut Agricultural Experiment Station during 1947.

Schread (1947), published an article in which is given an account of the control of Japanese beetle, the turf inhabiting ant *Lasius niger* var. *americanus* Emery and the chinch bug, by this insecticide. The proper amounts of chlordan to use, methods of application and results attained are discussed briefly. The red harvest ant, a serious pest in pastures, fields and yards in Oklahoma, and its control by chlordane was discussed by Brett *et al.* 1946. For a number of years various insecticides were used in an effort to suppress this insect but without complete success. Technical chlordan proved to be the best material tried to date, giving more rapid direct and final control than secured in the past with other toxicants. Within 2 hours large numbers of ants were killed by a 0.5 per cent solution. Not only were colonies destroyed within 24 hours by chlordane but no re-establishment of colonies occurred.

In early May, 1947, a chlorinated camphene[1] with the approximate empirical formula $C_{10}H_{10}Cl_8$, was first used in Connecticut as a 10-per cent dust at the rate of 8, 12, 16, 20 and 24 pounds of actual toxicant to the acre, for control of Japanese beetle grubs in turf. Five 0.125 acre plots were treated on the surface on May 12 at the aforementioned dosage levels, using 80, 120, 160, 200 and 240 pounds of 10-per cent dust to the acre. Owing to the small amount of material, especially at the lower dosage levels a fertilizer[2] was used as a diluent at a ratio of 1 pound of dust to 2 of fertilizer to increase the bulk of material and thus provide more uniform coverage. Results of the use of the insecticide are given in table 1.

All dosage levels of the toxicant gave good control, thus preventing maximum

Table 1.—Toxicity of chlorinated camphene to Japanese beetle larvae, 1947.

Actual Toxicant per Acre	Grubs per Sq. Ft.		Reduction	Grubs per[1] Sq. Ft.		Eggs per[1] Sq. Ft.	
	May 12	June 16	June 16	Aug. 19	Sept. 25	July 21	Aug. 19
8 lbs.	111	53.4	67.5%	4.5	0.4	6.0	0.5
12 lbs.	119	36.4	76.5	6.0	None	5.0	14.0
16 lbs.	107	26.0	80.4	3.5	1.8	8.0	1.5
20 lbs.	92	30.4	75.9	7.0	0.6	14.9	4.5
24 lbs.	92	24.2	79.1	2.0	None	26.5	0.0
Untreated				23.1	81.5	9.1	8.5

[1] Data represent the average of six diggings per 0.125 acre plot.

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[1] *Toxaphene*, Hercules Powder Co.

[2] *Milorganite*, a product of the Milwaukee Sewage Disposal Commission.

Table 2.—Toxicity of benzene hexachloride to Japanese beetle larvae, 1947.

Actual Gamma Isomer per Acre	Grubs per Sq. Ft.		Reduction	Grubs per[1] Sq. Ft.		Eggs per[1] Sq. Ft.	
	May 15	June 17	June 17	Aug. 19	Sept. 25	July 21	Aug. 19
.96 lbs.	108	46.0	70.1%	2.5	0.4	17.0	2.0
1.92 lbs.	92	44.8	67.2	None	1.8	2.0	1.5
2.88 lbs.	102	43.6	70.0	1.5	0.4	8.5	3.5
3.84 lbs.	110	39.0	73.8	6.0	5.0	0.0	6.0
4.80 lbs.	124.5	25.0	83.2	1.0	0.2	4.0	17.0
Untreated				23.1	81.5	8.5	9.1

[1] Data represents the average of 6 diggings per 0.125 acre plot.

grub injury in early June. By the latter part of September mortality of the grub population originating during the preceding summer months was almost 100 per cent at all dosage levels. The data on oviposition indicate that eggs are normally laid in treated turf.

Benzene hexachloride[1] in the form of a 50 per cent wettable powder containing 6 per cent gamma isomer, was applied against Japanese beetle grub populations at actual gamma isomer levels of .96, 1.92, 2.88, 3.84 and 4.80 pounds per acre. Each 0.125 acre plot was treated May 15 with the proper amount in 150 gallons of water and applied at 400 pounds pump pressure by a 16 nozzle spray boom. Table 2 gives the results attained.

Sufficient control was obtained by June 17, especially at the two highest dosage levels, to check serious grub injury to the turf. Turf which was more or less severely damaged recovered quickly with ample watering and rolling. Soil examinations in all plots in late September showed almost complete control of a heavy grub population as measured by average grub counts in adjacent untreated plots. The oviposition data do not indicate that this compound affects egg laying. Benzene hexachloride in turf leaves a persistent disagreeable musty odor which lingers for months, thus discouraging its use generally, especially on golf course fairways where members object to it.

Chlordan[2] a chlorinated hydrocarbon having the empirical formula $C_{10}H_6Cl_8$ was employed at four dosage levels: 8, 10, 16 and 24 pounds of actual chlordan to the acre. On May 20 a 2-per cent dust was applied on the surface to three 0.125 acre plots at 400, 800 and 1200 pounds of dust per acre. A summer treatment of 100 pounds of 10-per cent chlordan dust was diluted with 200 pounds of fertilizer to facilitate application and more uniform distribution of the toxicant.

Table 3 gives the results of all trials. When a 2-per cent dust was used, the apparent reduction in the over-wintering grub population was extremely high 4 weeks subsequent to treatment. The Japanese beetle population laid down during the succeeding summer months was killed as rapidly as the eggs hatched. On August 19 a few grubs were found in two of the three plots treated May 20, but they belonged to the preceding over-wintering

[1] *Lezone 50*, DuPont Co.

[2] *Riricol-2-D*, Riverdale Chem. Co., *Synklor-10-D*, U. S. Rubber Co.

Table 3.—Toxicity of chlordane to Japanese beetle larvae, 1947.

Actual Chlordane per Acre	Grubs per Sq. Ft.		Reduction	Grubs per[1] Sq. Ft.		Eggs per[1] Sq. Ft.	
	May 20	June 19	June 19	Aug. 19	Sept. 25	July 21	Aug. 19
8 lbs.	97.3	22.0	88.0%	.5	0	17.5	0.5
16 lbs.	76.0	13.8	93.6	.0	0	8.5	1.5
24 lbs.	102.6	4.8	98.7	.5	0	19.5	0.5
Untreated				48	117	9.1	8.5
	Aug. 13	Aug. 28	Aug. 28		Sept. 14		Aug. 28
10 lbs.	30	2.2	93.2		0.7		29
Untreated					71.3		

[1] Data represent the average of 6 diggings per 0.125 acre plot.

grub population, an abnormally higher percentage of which went through a 2-year rather than a normal 1-year cycle. Such grubs were deeper in the soil, 2 to 3 inches, than the new population and were apparently not feeding. Consequently they were not in immediate danger from the lethal action of chlordan and survived when all younger grubs nearer the surface of the ground were killed.

Plot examinations in late September showed the turf to be entirely free of grubs whereas in the untreated plots there were an average of 117 grubs per square foot. Large numbers of dead adult Japanese beetles were seen during the summer on the turf of the chlordane-treated plots. Examination of plots treated with other insecticides including DDT showed virtually no dead adults on the DDT plots and significantly fewer on the other chemically treated plots. It is believed a large percentage of beetles entering chlordane treated plots for egg laying died from the effects of the insecticide, although the oviposition data do not prove an inhibition of egg laying.

Chlordan used as a 10-per cent dust, 10 pounds actual toxicant per acre, August 13, gave 93.2 per cent mortality in 14 days of a grub population in the order of 30 per square foot of turf. By September 14, 1 month after treatment, control in the order of 99.02 per cent was estimated. Concurrently in the check plots grubs averaged 71.3 per square foot.

On September 17 a football field having an average grub population of 80 per square foot was treated with chlordane at the rate of 200 pounds of 5-per cent dust to the acre. Subsequently, for a period of 48 hours, eight large turf sprinklers were used in each of the 10-yard zones at hourly intervals, giving 4 hours of actual drenching to each zone. Alternately with sprinkling, the turf was firmed with a heavy roller. At the termination of sprinkling and rolling examination showed chlordane had immobilized the grub population. In spite of the severe test to which the turf was put by the cleats of football players, sprinkling and rolling for an additional week to 10 days resulted in saving 95 per cent of the turf. Ten days after the treatment 96 per cent of the grubs were dead. At this time there was an average of three grubs per square foot.

When chlordan was used in the manner described no phytotoxicity was seen. The insecticide did, however, result in additional vigor to turf and deeper color in the grass foliage.

Parathion[1] formulations, 0.25, 1 and 2 per cent, were used for Japanese beetle grub control August 22 at the rate of 1, 4 and 8 pounds respectively of the actual toxicant per acre, that is, 50 pounds of dust per plot or 400 pounds per acre. The first treatments were made August 22 between the hours of 11:30 A.M. and 1:00 P.M. The day was clear, hot and humid with a maximum air temperature during treatment of 87° F. At 3:00 P.M. each plot was thoroughly sprayed with 200 gallons of water to wash the parathion from the grass foliage into the soil. There was no rain until the afternoon of the fourth day when a heavy fall occurred. Daily mean temperatures for 5 days subsequent to treatment averaged 73.8° F.

Table 4.—Parathion. Average Japanese beetle grubs per square foot of turf and apparent reduction compared with untreated plots.[1]

Weeks After Treatment	Untreated Plots, Grubs per Sq. Ft.	0.25% Plot		1% Plot		2% Plot	
		Grubs per Sq. Ft.	Per Cent Reduction	Grubs per Sq. Ft.	Per Cent Reduction	Grubs per Sq. Ft.	Per Cent Reduction
2	85.0	22.4	69.7	4.6	91.8	2.6	95.2
4	88.3	7.0	88.3	2.8	94.9	0.2	99.6
6	88.3	2.6	97.1	None	100.0	None	100.0

[1] Data represent the average of 6 diggings per 0.125 acre plot.

Results of the first series of experiments are given in table 4. At the 0.25 per cent level parathion did not give desired control until the end of the fourth week following treatment. The 1-per cent level provided control of the grub population by the end of the second week and the 2-per cent level in less than 2 weeks.

The experiments of August 22 were repeated September 17 in every detail with the exception that 300 gallons of

[1] Thiophos, American Cyanamid Co.

Table 5.—Parathion. Average Japanese beetle grubs per square foot of turf and apparent reduction compared with untreated plots.[1]

Weeks After Treatment	Untreated Plots Grubs per Sq. Ft.	0.25% Plot		1% Plot		2% Plot	
		Grubs per Sq. Ft.	Per Cent Reduction	Grubs per Sq. Ft.	Per Cent Reduction	Grubs per Sq. Ft.	Per Cent Reduction
2	87.5	15.2	85.2	6.8	92.7	3.0	96.6
4	87.5	3.6	96.4	0.6	99.3	0.2	99.7

[1] Data represent the average of 6 diggings per 0.125 acre plot.

water were used per 0.125 acre plot instead of 200 gallons. The day was clear, warm and dry with maximum temperature of 76° F. Treatments were applied in early afternoon and were followed immediately by watering to remove the insecticide from the grass foliage. Heavy rain, 0.45 inches, fell 48 hours subsequent to treatment. Average mean air temperature for 8 days after the application was 54.2° F.

The results of the September 17 experiments (table 5) were considerably better than those of August 22. In 2 weeks in September 0.25 per cent parathion gave control comparable to that which was obtained at the end of 4 weeks in August. Proportionately the same degree of mortality was obtained from the 1- and 2-per cent parathion levels in autumn as in summer.

Turf samples were submitted at two week intervals to the American Cyanamid Company for assay to determine the residual value of parathion in soil. The results of the analyses are given in table 6. Lasting value of the toxicant is greatest in the autumn when soil and air temperatures are lower than during the summer. At extremely low doses this insecticide gives immediate control of excessive Japanese beetle grub populations without apparent injury to grass foliage to date, but insufficient time has elapsed to be certain no injury will occur. It is believed that the 1-per cent dosage level of actually 4 pounds of parathion per acre, or perhaps a little less, will be ample for Japanese beetle grub control.

Experiments with DDT at the established 25-pound level of actual toxicant to the acre were commenced on May 15, 1946 and followed through to the end of 1947. Forty-eight diggings were made per acre for results. The insecticide was used at a 15-pound level in the spring of the latter year. Results appear in table 7. Comparing the 25 pound level of DDT with the 10 pound level of chlordane it is seen that in a period of 2 weeks the latter toxicant gave 2.3 times greater mortality of Japanese beetle grubs than did DDT and 21.2 per cent more kill at the end of 4 weeks than DDT provided at the end of 5 weeks.

The residual effectiveness of DDT has been established by the Bureau of Entomology and Plant quarantine of the U. S. Department of Agriculture. Beyond 1 year the lasting value of chlordane is not at present known, owing to the fact this is the first year of experience under field conditions of Japanese beetle control. In any case, however, it is a much faster acting, more direct and more complete toxicant for grub control than DDT, chlorinated camphene or benzene hexachloride.

Table 6.—Soil analyses for parathion residue, 1947.

	Per Cent Parathion in Dust	Ppm. Found[1]				
		Sept. 13	Sept. 15	Oct. 1	Oct. 15	Oct. 31
Aug. 22	0.25	[2]0.1	0.2	0.1	<0.1 (0.02)	0.1
	1.0	[2]0.23	2.5	0.8	0.4	0.8
	2.0	7.1	3.8	1.9	0.2	0.6
Sept. 17	0.25			0.3	0.3	0.2
	1.0			5.5	1.7	5.4
	2.0			6.5	4.6	6.7

[1] Sampled only 1 inch of soil below surface.
[2] Sampled 2 to 3 inches of soil below surface.

It can be seen in table 7 that chlorinated camphene at the dosage levels 16 and 24 pounds of actual toxicant per acre gave slightly better kill of Japanese beetle grubs during the first season than DDT. Chlordan at the 10 pound level produced 2.3 times greater mortality of grubs in 2 weeks than 25 pounds of DDT and at the end of 4 weeks 21.2 per cent higher kill than DDT at the end of 5 yeeks. Parathion insecticide at 0.4 per cent the standard DDT treatment of 25 pounds of actual insecticide per acre produced in 2 weeks over twice the grub mortality resulting when DDT was used, and 18.6 per cent greater kill in 4 weeks than estimated for DDT in 5 weeks. Furthermore, parathion at an 8-pound level in 4 weeks accounted for 11.7 per cent higher mortality of grubs than an equal dose of chlordane gave in 5 weeks. At nearly comparable dosage levels of 1 and 4 pounds of actual toxicants per acre of parathion and benzene hexachloride the former insecticide gave in both instances better than 25 per cent greater mortality of Japanese beetle grubs in 4 weeks than the latter in 5 weeks.

ANT CONTROL IN TURF.—*Lasius niger alienus americanus* Emery, frequently a serious nuisance in well-kept turf, especially golf course greens, is encountered more often than all other species and is the most abundant of all species in numbers of individuals and colonies. It is a small brown ant that builds small single or clustered craters on the surface of the ground directly above its nest in turf and in open soil. To control this species in lawns, golf course greens or turf and unprotected soil in general, with chlordan, two methods of treatment were devised each of which is applicable to a distinct set of conditions.

The principle of the first method is to treat each individual ant nest separately, and this is applicable to turf areas where nests occur infrequently or at least not in great abundance. One-eighth of a teaspoon of chlordan, 50 per cent wettable powder, was placed in the center of each anthill and thoroughly watered into the galleries of the nest through the use of a 4-gallon pressure sprayer with the spreader removed from the nozzle, or a watering can with sprinkler removed. Another method of treatment consisted of adding one ounce of chlordan to each gallon of water in a small pressure sprayer. With the spreader removed from the nozzle the suspension was directed into each ant nest.

Table 7.—Comparative toxicity of soil insecticides to Japanese beetle larvae.

Insecticide	Actual Toxicant per Acre (Pounds)	Per Cent Mortality Subsequent to Treatment Weeks Later				
		2	5	19	55	72[2]
Chlordan	8	—	88.0	100.0		
	10	93.2	99.0[1]	—		
	16	—	93.6	100.0		
	24	—	98.7	100.0		
Benzene hexachloride	.96	—	70.1	99.5		
	1.92	—	67.2	97.8		
	2.88	—	70.0	99.5		
	3.84	—	73.8	94.2		
	4.80	—	83.2	99.7		
Chlorinated camphene	8	—	67.5	99.5		
	12	—	76.5	100.0		
	16	—	80.4	97.8		
	20	—	75.9	99.2		
	24	—	79.1	100.0		
DDT	25	41.2	77.8	95.9	97.1	97.6
	15	—	71.0	89.7		
Parathion	1	85.2	96.4[1]			
	4	92.7	99.3[1]			
	8	96.6	99.7[1]			

[1] 4 weeks after treatment.
[2] Third Japanese beetle generation since insecticide was applied to soil.

The principle of the second method of treatment is to apply chlordan, 50 per cent wettable powder, in suspension to every square foot of golf course green, or other turf to be protected. Four ounces of chlordan were added to 75 to 100 gallons of water and applied to 1000 square feet of turf with a hose and garden nozzle, the latter open as wide as possible, at 100 pounds pressure, giving a coarse rather than a fine spray.

Following treatment, the turf was watered with 50 to 60 gallons of clear water per 1000 square feet. Not only did chlordane eliminate all ant colonies present at time of treatment, but protection from re-establishment lasted for a number of weeks (Table 8). Treatment may be repeated if necessary at the end of this time. The use of a multiple nozzle spray boom providing a mist spray at high pump pressure was unsatisfactory owing to poor coverage and the great loss of material through wind-drift. Loss may also be due in part to evaporation. This has not, however, been entirely proven.

Occasionally the mound building ant, *Formica exsectoides*, becomes troublesome when it constructs mounds in parks, recreational areas, picnic groves, pastures and along roadsides. This insect is the builder of our largest anthills. New colonies are frequently formed by fission or breaking up of an older colony. As a result a number of colonies are sometimes established in a limited area. Such was the case in the abandoned pasture where experiments in control of this species of ant by chlordan were carried out.

Mounds may vary in size from a few inches in diameter and an inch or so in height to 8 feet or more in diameter and over 12 inches high. In a series of experiments using varying small dosages of the insecticide on different size mounds, their respective colonies were destroyed completely in a matter of hours. Table 9 gives the results of the experiments. Chlordan, 50 per cent wettable powder, is a quick acting, direct and efficient toxicant when applied to kill colonies of this ant.

Live worker ants of *Formica exsectoides* were dusted with chlordane and confined to clean cardboard cages. Another group not dusted was confined in similar cages, the bottom of which had been lightly dusted with the insecticide. Excitation set in almost immediately among both groups of ants. In 12 to 15 minutes the insects showed signs of paralysis, more pronounced among those receiving direct application of the toxicant. Ninety minutes after treatment all ants in both tests were immobile and on their backs the only signs of life manifest being an occasional twitching of the legs. Five to six hours after coming in contact with chlordan all ants were dead.

Two weeks following treatment of one of the largest mounds a thorough examination of the mound and nest was made to a depth of 3 feet below the surface of the ground. Countless dead workers were found in the galleries of the nest as well

Table 8.—Control of *Lasius niger alienus americanus* in turf.

Ant hills at Treatment	Chlordan 50-W Used	Ant hills Present—Weeks Later									
		1	2	3	4	5	6	7	8	9	10
750	One-eighth teaspoon per anthill	0	28	98							
750	5 oz. in 5 gal. of water	0	157								
850	5 oz. in 80 gal. of water	0	100								
	To 1000 sq. ft.										
350+	4 oz.	[1] 75	75+	100	125	142					
300+	8 oz.	25	30	57	65	73	88				
100+	2 oz.	0	15	23	13	12	14	14	13	10	
150+	4 oz.	0	0	0	2	8	1				
450	4 oz.	0	0	0	0	4	8	8	8	8	1
125+	4 oz.	[2] 0	0	0	0	0	0	1	2		
823	8 oz.	0	0	0	0	0	0	1	2	3	5
79	12 oz.	0	0	0	0	4	7	7	5	4	
90	16 oz.	0	0	0	0	0	0	0	4	1	

[1] Used a 16 nozzle spray boom—mist spray—much loss of Chlordan.
[2] Used garden hose nozzle wide open—coarse spray—no loss of Chlordan.

Table 9.—Control of *Formica exsectoides* by use of chlordan.

Mound No.	Date Treated	Dimensions of Mounds, Inches	Dose Ounces	Results—Days Later				
				20	2	6	7	50
	1947							
1	July 15	14×12× 6	1.5				Colony completely killed	No activity
2	15	18×14× 7	1.5				Colony completely killed	No activity
3	23	20×20× 4	1.0	Colony completely killed				No activity
4	15	24×24×12	3.0		Colony completely killed			No activity
5	23	30×30× 8	2.0	Colony completely killed				No activity
6	15	36×36×12	5.0		Colony completely killed			No activity
7	23	36×40× 9	2.0	Colony completely killed				No activity
8	7	48×40×12	8.0				Colony completely killed	No activity
9	Aug. 27	96×84×10	5.0		Several ants seen on perimeter of mound	Colony completely killed		

as thousands of dead eggs, larvae and pupae. Some of the last were taken to the laboratory. No adults emerged.

Other species of ants, *Formica pallidefulva* subsp. *nitidiventris* Emerg. and *Formica fusca* vor. *subsericea* Say, working in open soil at the base of shrubs and in turf were controlled successfully when chlordane[1] 50 per cent wettable powder was fogged into the openings of the nests.

In preliminary experiments the chinch bug, *Blissus leucopterus* Say was eliminated from bent grasses in golf course greens and also from lawns of standard grass mixtures by chlordan 5 per cent dust at the rate of 6 to 10 pounds to each 1000 square feet of turf. The 6-pound level gave as quick and complete a kill as the 10 pound. It is therefore believed 5 to 6 pounds of the toxicant per 1000 square feet of turf is sufficient for chinch bug control.

SUMMARY.—Chlordan, Benzene hexachloride and parathion were compared with DDT for Japanese beetle grub control. Toxaphene at 16 and 24 pounds to the acre gave better results than DDT during the first season. Chlordan at 10 pounds to the acre killed more than twice as many grubs in 2 weeks than DDT at a 25-pound level. Parathion at 0.4 of the standard DDT treatment of 25 pounds to the acre produced in two weeks better than twice the grub mortality obtained with DDT. At an 8 pound level parathion accounted for 11.7 per cent higher mortality of grubs in four weeks than an equal dose of chlordan gave in five weeks. At nearly comparable dosage levels of 1 and 4 pounds of actual toxicants per acre, of parathion and Benzene hexachloride, the former gave better than 25 per cent greater mortality of grubs in four weeks than the latter in five weeks.

The soil inhabiting ant *Lasius niger* var. *americanus* was successfully eliminated from turf when chlordan was used at various dosage levels. Four ounces of 50 per cent wettable powder to 1000 square feet of turf destroyed all ant colonies present and gave many weeks protection from re-establishment.

The mound building ant *Formica exsectoides* was destroyed completely by the use of chlordan 50-W, at low dosage levels. Adult ants were killed in five to six hours, eggs did not hatch and pupae produced no adults. *Formica pallidefulva* subsp. *nitidiventris* and *Formica fusca* var. *subsericea* ant species working in open soil at the base of shrubs and in turf were controlled by chlordan. Six to ten pounds of chlordan 5-D to 1000 square feet of turf gave complete control of the chinch bug, *Blissus leucopterus*.

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SCIENTIFIC NOTES

DDT for Ant Control in Lawns

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During the summer of 1947 some brief experiments were conducted in the control of two species of ants which were infesting and damaging lawns. These ants, as determined by M. R. Smith of the Division of Identification, were the silky ant, *Formica fusca*, var. *subsericea* Say, and *Lasius niger*, var. *neoniger* Emery. The treatments were applied to randomized plots each 1 yard square, and each treatment was applied to two or four plots. A preparation containing 50 per cent of DDT was used as the source. When applied as a spray the proper dosage for each plot was mixed with 1 quart of water and applied with a compressed air sprayer. When applied as a dust the DDT was diluted with talc to make a 10 per cent dust and the dosage for each plot was sprinkled evenly over the surface by hand.

The silky ant was infesting parts of a lawn and an adjacent vegetable garden in Staunton. The nests were so common over much of the lawn that no grass and little other vegetation could grow. The surface of these areas was honeycombed by the entrances and it had a spongy feel when walked upon. Several spots in the garden were so heavily infested that neither seedlings nor transplants could become established. Ten plots were laid off on this lawn on June 2. DDT dust and spray were applied at the rate of 2.5 grams and 5 grams of actual DDT per square yard, giving four different treatments and a check in each replication. Just before the treatments were applied the ants on the surface of each plot were counted as accurately as possible. Similar counts were made 1, 2, 5, and 7 weeks after the treatments. At the time of each examination after the first the dead ants were collected from the surface of each plot and counted. The results of these treatments are given in table 1. Activity of the ants in the treated plots declined steadily. It was found that ants were still active on the surface of one of the plots sprayed with 2.5 grams of DDT 7 weeks after treatment, and that these ants seemed to come from many nests under a low stone wall near one side of the plot. A liberal amount of DDT was applied along the base of this wall, and all activity soon ceased in the plot. By the time of the final examinations of the plots there had been a considerable drop in activity in the check plots, which were almost surrounded by treated plots. This decline may have been due to ants from these plots being killed by working over the adjacent treated plots, as there was no such apparent reduction in numbers of ants in other parts of the lawn. The vegetation on the lawn also showed the effect of the decline in activity of the ants, for grass and weeds had covered the surfaces of the treated plots, while untreated areas were still almost bare.

Treatments were also applied in the vegetable garden, but the scattered nature of the infestation here prevented any systematic arrangement of the treatments. Dust and spray were about equally effective, but the sprays gave quicker results. Dust was more quickly effective when it was mixed with the soil about a nest entrance than when it was sprinkled on the surface. Dust was also more quickly

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Table 2.—Results of the application of DDT to the soil to control an ant, *Lasius niger*, var. *neoniger* in sod, Waynesboro, Virginia, 1947.

Dosage and Method of Application[2]	Number of Mounds in Plots[1]			
	Before Treatment	Weeks After Treatment		
		1	2	5
1 gm. dust	37	18	11	1[3]
2 gms. dust	26	11	7	0
4 gms. dust	33	11	7	1[3]
8 gms. dust	16	4	4	0
1 gm. spray	41	22	15	1[3]
2 gms. spray	37	19	10	0
4 gms. spray	47	8	5	0
8 gms. spray	17	6	3	0
Check	38	36	35	27

[1] Each plot was 1 yard square. The figures in the table are the totals for the plots which received each treatment. The 8-gram dosages were applied to two plots each and all other treatments to four plots each.
[2] Dosages are given in amount of actual DDT per square yard.
[3] After 8 weeks there was no sign of activity in any treated plot.

Table 1.—Results of the application of DDT to the soil to control the silky ant in a lawn, Staunton, Virginia, June 2, 1947.

Dosage and Method of Application[2]	Number of Ants Observed on Surface of Plots[1]								
	Before Treatment	After an Interval of							
		1 Week		2 Weeks		5 Weeks		7 Weeks	
		Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead
2.5 gms. dust	39	34	166	11	159	7	16	0	0
5 gms. dust	37	23	164	8	120	0	0	0	0
2.5 gms. spray	50	10	246	7	20	3	17	3	5
5 gms. spray	40	6	267	4	12	0	0	0	0
Check	35	45	5	33	28	16	68	16	34

[1] Each plot was 1 yard square. The figures in the table are the totals for two plots receiving each treatment.
[2] Dosages are given in amount of actual DDT per plot of 1 square yard.

effective when its application was followed by a shower than when the soil remained dry.

Lasius niger, var. *neoniger*, was infesting a lawn near Waynesboro. The grass on this lawn was kept closely clipped, and the small mounds thrown up around the entrance holes were very conspicuous, particularly during periods of prolonged dry weather. On July 17 DDT was applied to 16 plots of this lawn. The rates of application were 1, 2, 4, and 8 grams of actual DDT per square yard, and each dosage was applied both as a dust and as a spray. On August 8 DDT was applied to 12 new plots, the 8 gram dosage being omitted.

The mounds on each plot were counted and levelled after the DDT was applied. Thus the entrance holes of the nests were filled. Rebuilt mounds, indicating reopened nests, were counted at weekly intervals for 5 weeks after the treatments. The results of the two experiments are combined in table 2. There was a gradual decline in the activity of the ants in the treated plots. This reduction was slightly more rapid in the sprayed plots than in the dusted plots, but the difference was too small to indicate any difference in the value of spraying and dusting. The heavier dosages resulted in a more rapid reduction in activity. However, even the dosages of 1 gram per square yard, which is equivalent to 2.45 pounds of 10 per cent DDT per 1000 square feet, resulted in an almost complete absence of activity in 5 weeks. After 8 weeks there was no sign of activity in any of the treated plots. Activity also declined in the check plots. Since there was no apparent decline in activity in parts of the lawn more distant from the treated plots, this drop in the check plots was probably due to the nearness of the treated areas.

The results of these brief tests indicate that light applications of DDT have some promise as a means of reducing the injury caused by some species of ants in sod. Since the dosage of DDT recommended for control of the Japanese beetle larvae is equivalent to 2.45 grams of actual DDT per square yard, it is considerably heavier than some of the dosages which showed promise against ants.

Benzene Hexachloride and Cornstarch as a Roach-Control Combination[1]

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Slade (1945) first reported that the gamma isomer of benzene hexachloride was toxic to roaches. McGovran & Piquett (1946) compared this material in a dust with dusts of pyrethrins, DDT, and sodium fluoride. They found it the most toxic of the four materials to German roaches, but less toxic than pyrethrins and DDT to the American roach. Technical benzene hexachloride has an objectionable odor, which may be carried over into the purified gamma isomer.

In the rearing of roaches for test purposes at the Agricultural Research Center, Beltsville, Md., a commercial dog food, in large, dry pellets, is used for food. Roaches are known to prefer starchy foods (Rau 1946). This paper reports results of tests against roaches with tablets and powders to which the gamma isomer of benzene hexachloride and cornstarch has been added.

TABLET TESTS.—Tablets were made from dog food containing 2 per cent of gamma-benzene hexachloride, cornstarch, and both these materials. The gamma-benzene hexachloride dissolved in acetone, was added to the powdered dog food, the mixture evaporated to dryness over a water bath, and then pressed into cubes. The cornstarch was added to the dried mixture when it was included. The tablets were fed to 15 adult females of the American roach, *Periplaneta americana* (L.), for 10 days. No other food was given to the insects. The tests were replicated four times.

The tablets containing both cornstarch and benzene hexachloride in dog food killed all the roaches, whereas those containing only gamma-benzene hexachloride killed 27 per cent and those containing only cornstarch killed 3 per cent. The powdered dog food in all cases masked the odor of the benzene hexachloride.

Similar tablets were tested against the American roach and three other species, viz. the German roach, *Blatella germanica* (L.), the oriental roach, *Blatta orientalis* L., and the brown-banded roach, *Supella supellectilium* (Serv.). In all cases mortality was 100 per cent after 4 days.

Further tests were made to determine whether the increased efficacy of the gamma-benzene hexachloride-cornstarch tablets was due to the greater attractiveness of cornstarch to the roaches, and consequent greater consumption. Fifteen adult females of the American roach were allowed to feed for 2 hours on tablets containing cornstarch, gamma benzene hexachloride, and dog food in the proportions used in the previous tests and also on tablets made of dog food alone, cornstarch alone, and cornstarch containing 2 per cent of gamma-benzene hexachloride. The tests were replicated six times. All the roaches were starved prior to the tests.

The average amounts of the various kinds of tablets eaten by the roaches are given below:

	Milligrams
Dog food:	
Alone	21
With cornstarch	31
With gamma-benzene hexachloride	6
With gamma-benzene hexachloride and cornstarch	5
Cornstarch:	
Alone	75
With gamma-benzene hexachloride	34

The data show that feeding on the tablets by the roaches was not increased by the addition of cornstarch where benzene hexachloride was present. Therefore, increased kill must be due to synergistic action of the cornstarch.

TESTS WITH POWDERS.—Further tests were made to determine the effectiveness of powders containing gamma-benzene hexachloride.

The powders contained the same percentages of gamma-benzene hexachloride and cornstarch as did the tablets, but the carrier was an insecticidal grade of fuller's earth[1] instead of dog food. The crystallizing-dish technique of McGovran & Piquett (1946) was used. Four replicated tests were made in which 15 female American roaches were exposed to 40 mg. of powder. The average mortality after 10 days was only 12 per cent with the powder containing gamma-benzene hexachloride and 55 per cent when cornstarch was added. Two per cent of cornstarch in fuller's earth gave only 3 per cent kill. This increase in mortality is further evidence of the synergistic effect of cornstarch.

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[1] Patent applied for.

SUMMARY.—Tablets containing 2 per cent each of gamma-benzene hexachloride and cornstarch in powdered dog food were found to be highly toxic to roaches. A powder containing the same materials with fuller's earth substituted for the dog food, was likewise toxic. The powdered dog food masked the musty odor of benzene hexachloride. The increased toxicity of benzene hexachloride where cornstarch is present indicates synergistic action.

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Tests on Control of Elm *Scolytus*

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More and more elm trees in southern New England are dying of the Dutch elm disease—bark beetle combination. Laboratory tests were conducted in 1947 to determine the relative efficacy of arsenate of lead and DDT in preventing crotch feeding by the European elm bark beetle, *Scolytus multistriatus* Marsh.

Infested bark of American elm, *Ulmus americana*, was obtained in February 1947 from Philadelphia, Pa. On April 4 and 17, infested American elm bark from Stamford, Connecticut, was received. This elm bark was placed in rearing cages in the Insectary, where outdoor temperatures were maintained, and observed for emergence.

Emergence of adult *Scolytus* started from the Philadelphia material on May 29, from the Stamford material on June 12. June 11 was the first hot day of spring, the temperature reaching 86° F.

Three small potted American elm trees were sprayed and placed under celluloid covers inside the Insectary. The schedule of treatments was as follows:

No. 1. Sprayed with arsenate of lead,[1] 6 lbs per 100 gallons, on June 13th.
No. 2. Sprayed with wettable DDT powder,[2] 2 lbs. per 100 gallons on June 13th.
No. 3. Unsprayed. Check.
No. 4. Mist-blown with DDT[3] crystals (89 per cent), 1 lb. dissolved in 3 pints of xylene and diluted with 5 pints of kerosene, solution on July 7th.

Living *Scolytus* beetles were then introduced into the cages with all the trees except the untreated check using 20 or more beetles per caged tree every day or every other day, as long as emergence continued, which was until June 26 in the case of the Philadelphia material and until July 18 from the Stamford material.

The *Scolytus* beetles, on introduction into the cages, went immediately to the twig crotches where they started feeding.

In the case of the untreated tree only eight beetles were introduced. These eight beetles killed the tree almost to the ground, by girdling, within 10 days. Apparently there was no Dutch elm disease fungus present on them as the trunk below the point of twig-branching was still alive and sent out new growth later in the season.

It was 9 days before the beetles were able to get through to the sapwood on the arsenate of lead sprayed trees. It took longer here for the beetles to be killed as a result of feeding on the stomach poison in the sprayed twig-crotches than it did for them to be killed by contact of their feet with DDT.

In the case of tree 2 it was 21 days before the beetles penetrated the DDT barrier.

In the case of tree 4 (mist-blown with DDT solution) the entire tree died within 3 weeks as a result of kerosene penetration of the tender bark. The *Scolytus* beetles do not attack dead twigs, hence no feeding occurred on this tree. It was impossible to determine how long protection from crotch-feeding could be obtained from *Scolytus* in this case because of the death of the tree.

There was slight arsenical injury to the leaves of of tree 1, about equal to the amount of spray injury from the wettable DDT mixture in case of tree 2. However, for practical purposes, both the arsenate of lead and the DDT gave protection throughout the season under these conditions with a minimum of foliage injury.

It is of interest to note that individual beetles of the common elm borer, *Saperda tridentata* Oliv., were apparently unaffected by the DDT, some of them living as long as 10 days in the cage. Those in the arsenate of lead cage, however, died of arsenical poisoning within a few hours after introduction.

What are the practical implications of these tests? I think they definitely indicate that, by proper timing, either arsenate of lead or wettable DDT may give satisfactory protection from *Scolytus* crotch-feeding if applied to the twig crotches in sufficient amounts. In the case of DDT applied by a mist blower a fair amount of protection against *Scolytus* was obtained in the 1947 large scale outdoor applications. There has, however, been considerable oil injury on many elms so treated.

A survey was made of approximately 700 trees in southwestern Connecticut, Westchester County, New York, and New Jersey which had been given proper sanitation, *i.e.*, pruning and feeding when necessary and spraying with arsenate of lead once or twice a season. Dormant applications of miscible oil were given periodically to control elm bark louse and aphids. Of these 700 trees, 5 have died during the past 10 years from the combination of Dutch elm disease and *Scolytus* attack. This indicates loss of about 1 per cent of well-cared-for elms. Contrast this figure with the 25 per cent of street and park elms in a certain Connecticut city which have died of the combination of Dutch elm disease and *Scolytus* during the past 18 years where only mediocre care had been given, or in some cases, during the war years, when they had been completely neglected.

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[1] *Formula:* Nurexform Arsenate of lead powder @ 6 lbs./100 gal. plus Filmfast spreader and sticker @ 8 oz./100 gal. Nurexform made by DuPont Chemical Co., Wilmington, Del. Filmfast made by General Chemical Company, Philadelphia, Pa.

[2] *Formula:* Deenate 50W (50% DDT) @ 2 lbs./100 gals. DuPont Chemical Co., Wilmington, Del.

[3] *Formula:* Westvaco DDT crystals (89%) @1 lb. dissolved in 3 pints of Xylene and diluted with 5 pints of kerosene. Westvaco Chlorine Products Corp., Carteret, N. J.

Chlorinated Insecticides for Control of the Potato Flea Beetle

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This test was designed to compare the effectiveness of several formulations of DDT and of the chlorinated insecticides Chlordan, methoxy DDT and chlorinated camphene[1] (Parker & Beacher, 1947) for control of flea beetles, leafhoppers and aphids on potatoes. Leafhoppers were present in such small numbers in 1947 that they caused little damage. Aphids also were of no consequence in the plots. Therefore the results are confined to control of the potato flea beetle and to the effect of the treatment on yield of potatoes.

METHODS.—Katahdin potatoes were planted April 28, using the spiral arrangement of Horsfall & Rich. This system provides for 10-row plots replicated four times in randomized blocks. The principal advantage of the design is the convenience and ease of application of materials using a power sprayer on small plots and approximating the performance of field sprayers. Application was made using a three-nozzle portable boom (one nozzle on each side directed into the plant and one nozzle spraying directly down into the plant). Applications were made June 4, 11, 19 and 26, July 3, 11, 17 and 24 and August 1. Late blight had appeared when the final application was made, and zinc ethylene bisdithiocarbamate[2] was applied to all plots, including checks, at the rate of 1 pound in 50 gallons of water. The same fungicide was also applied on August 7 and 15 without insecticide.

Damage by flea beetles was estimated on June 18 for the overwintering adults, and on July 24 for the summer generation, using the system described by Horsfall (1945). The crop was harvested in October and the number and weight of tubers per plot recorded.

MATERIALS.—Two samples of DDT wettable powder, one finely micronized (average particle size 10 to 20 microns) and the other ball-milled (average 25 to 35 microns) were applied.[3] These were the same samples as those used in tests reported by Woodruff & Turner (1947). Four emulsions were used: (1) a laboratory preparation containing 25 per cent DDT in *Sun Solvent 1547* with 2 per cent emulsifier.[4] (2) a proprietary 25 per cent DDT emulsion (A), (3) a proprietary emulsion containing 34 per cent DDT and (4) a proprietary emulsion (B) containing a solvent of considerable insecticidal value and with 30 per cent DDT.

The chlordan and methoxy DDT preparations were commercial wettable powders containing 50 per cent insecticide. The chlorinated camphene was a 25 per cent wettable powder.

With the exception of the finely micronized DDT, the highest concentration of toxicant was 1 pound in 100 gallons of water. Since the finely micronized material was shown to be of high toxicity, it was applied at a concentration of 8 ounces in 100 gallons. At least two lower concentrations of each material were used in the dosage series and all materials were diluted on the basis of DDT content.

RESULTS.—A summary of the data is given in table 1. The finely micronized DDT was more effective in controlling flea beetles than any other material used at equal concentration. (Probability greater than .01 by the method of Wilcoxon) (1947). For the second successive season fine particle size was more effective than coarse, and wettable powder more effective than emulsions (Woodruff & Turner, 1947, 1948). Chlordan, methoxy DDT and chlorinated camphene were less effective than finely micronized DDT. Within the emulsions there were no differences that were significant statistically.

Table 1.—Per cent reduction in flea beetle damage.

MATERIAL	CONC. TOXICANT, LBS.-100 GALS.	JUNE 18	JULY 24	YIELD, LBS. IN 4 10-FOOT PLOTS
Ball-Milled DDT Spray Powder	1	77	60	83.4
	.5	58	49	87.9
	.25	54	38	83.0
	.125	26	22	96.9
Finely Micronized DDT Spray Powder	.5	86	67	88.9
	.25	78	59	93.1
	.125	54	36	94.6
Chlordane Spray Powder	1	78	60	93.6
	.5	67	44	90.2
	.25	48	35	90.9
Methoxy DDT Spray Powder	1	84	59	79.4
	.5	66	50	79.7
	.25	44	33	88.5
Chlorinated Camphene Spray Powder	1	72	60	58.2
	.5	61	36	85.7
	.25	49	25	79.9
Laboratory DDT Emulsion	1	82	67	96.5
	.5	73	52	84.8
	.25	35	39	92.7
	.125	34	22	79.9
Commercial Emulsion, 34% DDT	1	92	74	76.1
	.5	68	54	90.9
	.25	54	41	79.4
	.125	55	22	78.8
Commercial Emulsion A, 25% DDT	1	82	66	72.7
	.5	73	52	95.5
	.25	58	35	96.3
	.125	50	25	94.8
Commercial Emulsion B, 25% DDT	1	85	61	72.9
	.5	70	47	83.9
	.25	64	35	82.3
	.125	44	22	94.7
No Treatment				87.9

As far as yields are concerned, little can be said. There were no statistically significant differences even between the low yields following applications of chlorinated camphene and the highest yields. Little difference in yield between treated and untreated plants would be expected in the absence of any serious pests except flea beetles, which did not kill untreated vines.

Marked foliage injury appeared soon after the second application of the high concentration of chlorinated camphene. As the season progressed the vines appeared to be stunted, and the yield was less than the yield from untreated plants. In fact, the yield of all concentrations of this material was less than the untreated check. Yield following methoxy DDT was only slightly better although no definite foliage injury was noted.

Commercial emulsion B also caused injury to the vines at the high concentration which was at least twice the amount usually used on potatoes.

SUMMARY.—For the second successive season,

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[1] *Toxaphene.*

[2] *Dithane Z-78.*

[3] These materials were laboratory preparations furnished by the Pennsylvania Salt Mfg. Co., Philadelphia, Pa.

[4] *Triton X-100.*

DDT spray powder of fine particle size provided significantly better flea beetle control than coarse particle size, and a higher yield of potatoes.

Likewise control of flea beetles by the fine particle sized DDT was superior to control by any of the four emulsions used.

DDT provided better control of flea beetles than chlordan, methoxy DDT or chlorinated camphene. Yields following methoxy DDT and chlorinated camphene were especially low.

Chlorinated camphene caused definite foliage injury at the high concentration.

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Rearing Methods for German and American Cockroaches[1]

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In the course of investigations of insecticides two species of cockroaches, *Blattella germanica* (L.) and *Periplaneta americana* (L.), were utilized as test insects. Experience with these species demonstrated that it was advantageous to maintain laboratory cultures under controlled conditions and on a known-age basis. As work progressed through a series of studies[3] methods by which such cultures could be maintained in a routine manner were developed, and have been used continuously since 1940 at Rutgers University. They are described as follows.

The cultures of both species are maintained in an air-conditioned laboratory in which the temperature is held at 75° F. ±2° with the relative humidity at 60 per cent ± 10 per cent. These conditions are not the optimum for the most rapid development of the insects, but they represent conditions nearest to optimum under which humans can work with reasonable comfort.

The cultures are so established that the age of all individuals is known within the range of 1 week. Minor modifications of procedure would permit the establishment of the stock more or less frequently with the age of the individuals known within a narrower or wider range.

To prevent the escape of roaches into the laboratory all the rearing and handling is done on tables protected by a moat containing oil.[4] This moat is provided by attaching a metal trough, 2 inches wide and 2 inches deep, about the edge of the table. The upper inner edge of the trough is constructed to overlap the top of the table to the distance of 2 inches. This inner edge is sealed to the table surface by adhesive tape. The trough is filled with oil to the depth of 1 inch. This protective device is effective in preventing the establishment of a roach infestation in the laboratory. Cages and equipment to be removed from the tables are freed of roaches by immersion in boiling water.

GERMAN COCKROACH.—The young nymphs for the establishment of the cultures are obtained from hatching cages in which reproducing females are confined. The hatching cage consists of a wire-screen cylinder resting on platforms within a battery jar. The females for reproduction are confined within the screen cylinder and the young nymphs escape, on hatching, to the platforms in the battery jar. The battery jar used is 6 inches in diameter and 8 inches deep. Two plywood or fibre-board platforms, each with four legs 0.25 inch long, are placed, one on top of the other, in the bottom of the jar. These platforms are of a size to fit easily into the jar and are of the form of a circle with two opposite segments on approximately a four-inch chord removed. The screen cylinder is 4.25 inches in diameter and 6 inches high. The bottom and the lower 3 inches of the side are constructed of 10-mesh wire screen. The upper 3 inches of the side is a solid metal collar. Cages constructed of copper or stainless steel have been used successfully. A water supply is provided both within the screen cage and on the upper platform outside the cage. A convenient watering device consists of a 15 cc. wide mouth bottle inverted in the bottom of a 50×10 mm. culture dish. A triangular notch in the edge of the mouth of the bottle permits a controlled flow of water from the bottle. A roll of cotton in the culture dish around the circumference of the bottle prevents drowning. Food in the form of pellets of dog food is placed in the screen cage. A small amount of sugar and some pulverized dog food is provided on one of the lower platforms. About 100 gravid females are placed in each screen cage. A thin film of vaseline on the metal collar prevents their escape. Once each week the screen cage is removed and any young nymphs adhering to it dislodged with a brush. These, with the young nymphs in the battery jar, are used for the establishment of the new stock. After the removal of the nymphs, the supply of gravid females in the screen cage is replenished and this cage established anew in a battery jar for another week. Five hatching cages in continuous operation yield about 2000 young roaches per week.

The young roaches are transferred from the hatching cages to battery-jar rearing cages for subsequent development. This cage consists of a battery jar, 6 inches in diameter and 8 inches deep, containing 10 plywood or fibre-board platforms, each approximately 4.12 inches square and having four legs 0.25 inch long. Wire brads or machine screws serve adequately as legs. These platforms are placed one on

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[3] Successively, a research fellowship supported by the Bristol-Myers Co., New York, N. Y., independent studies of the author and a research fellowship supported by Merck & Co., Inc., Rahway, N. J.

[4] *Mentor 28*, Standard Oil Co. of N. J. (Gravity ° A.P.I., 42.0; Specific Gravity @60° F., .815; Flash °F., 270; Boiling Range °F., 518–618.)

top of another in the jar, spaced 0.25 inch apart by means of their legs. This provides much extra floor space on which the roaches may develop. A thin film of vaseline is spread on the inner edge of the jar at the top to prevent escape of the roaches and the jar is closed with a cotton gauze cover. Pellets of dog food are provided as food and a water supply is provided on the upper platform. Four hundred roaches can be reared to maturity in a single cage of this type.

In order to prevent the establishment of a mite infestation the roaches are transferred to a clean cage at the end of 5 weeks. No further maintenance work is required with the exception of the replenishing of the water and food supplies.

Under the above conditions the majority of the roaches reach the adult stage at the age of nine weeks.

Roaches are immobilized for sorting prior to testing by chilling in a refrigerator at 30°±2° F.[1] The roaches are shaken off the platforms into a clean battery jar for this step. They cannot be kept under refrigeration for more than 2 hours without affecting their resistance.

By the use of this method a large stock of test insects of uniform developmental background and known age can be maintained. One technician working 6 hours a week can provide 2000 roaches weekly for testing as adults at the age of 10 weeks. Only 30 square feet of table space is required for such a supply.

AMERICAN COCKROACH.—A constant supply of egg capsules is available from the cages containing adults in the material taken from the cages at each of monthly cleanings. The capsules are sorted from the refuse by hand and placed in a glass jar in a layer no thicker than 0.25 inch for hatching.

Once each week all the freshly hatched nymphs are removed with the aid of a soft camel hair brush. Four days prior to this removal date water is provided for the nymphs from any convenient device such as saturated cotton in a shallow container. At the same time, a small lump of sugar is provided. The water and sugar are supplied intermittently to discourage the development of mold and mite infestations on the egg capsules.

The nymphs removed from the hatching jars are transferred to battery-jar cages for the first 3 months of their development. This cage is similar to the one described for the rearing of the German cockroach earlier in this paper with the exception that the bottom of the battery jar is covered with a layer of cotton gauze or filter paper before the platforms are placed in position. This prevents mortality among the young roaches resulting from their inability to regain their feet if they fall on their backs on the smooth glass bottom. Escape from the jar is prevented temporarily by a thin film of vaseline on the inner edge of the top of the jar and permanently by closing the jar with a cotton gauze cover. Food is provided to the young roaches in the form of a small amount of granulated sugar and some pellets of dog food. The sugar is supplied only once, at the establishment of the new colony. The dog food is maintained as the standard diet. Water is supplied from a suitable device on the upper platform. Four hundred roaches can be reared to the age of 3 months in a single cage of this type.

At the age of 3 months the roaches are transferred to a screen-covered cage for the remainder of their developmental period. This cage is rectangular, 12 inches long, 8 inches wide, and 6 inches high, with wooden floor and framework and a sliding glass front. It is covered on the back, top, and two sides with 16-mesh wire screen. It contains seven plywood or fibre-board platforms each 8 inches long and 6.5 inches wide, and each with four legs 0.5 inch long. These platforms are placed one on top of another in the cage so that they are spaced 0.5 inch apart by means of their legs. The water is supplied from a 1-ounce squat-type ointment jar placed on the floor of the cage in front of the platforms. The jar is filled with cotton gauze which is kept saturated with water through a 10 mm. glass tube touching the cotton and feeding from a bottle suspended in an inverted position on the side of the cage. Pellets of dog food are provided on the floor of the cage as food. Each cage will accommodate 150 roaches through their development from the age of 3 months to maturity.

The maintenance of the cultures requires the replenishment of the water and food supplies when necessary, and the removal of the debris from the floors of the screen cages once monthly. This latter step is accomplished with the assistance of a 12-inch spatula. Most of the excess food and fecal matter is deposited by the roaches outside the cages through the screen and this deposit on the tables must be cleaned up periodically.

Under the conditions outlined above, the majority of the roaches reach the adult stage at the age of of seven months.

Transfers of the roaches may be made with the assistance of immobilization by chilling.[2] This is done in a refrigerator in which the temperature is maintained at 30°±2°F. A chilling period of approximately 2 hours is necessary for the immobilization of the roaches in either the battery-jar or screen cages.

This method permits the maintenance of a large and constantly replenished laboratory culture of test insects of uniform developmental background and known age. A culture which provides for testing, each week, 1600 adult roaches of the age of 9 months has been maintained by one technician working 12 hours per week. This culture requires 125 square feet of table space.

[1] Since the original development of these techniques it has been found that roaches may be immobilized conveniently and without effect on their resistance by anaesthetization with carbon dioxide, a procedure which has been observed in several other laboratories.

[2] Recent communication from Dr. P. Granett and Dr. L. E. Hagmann of Rutgers University advises that anaesthetization with carbon dioxide offers advantages over chilling as a method of immobilization.

A *Phyllobius* Species, a New Pest and Its Control on Arborvitae[1]

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During late April 1947, a Rhode Island nurseryman reported to the writer the presence of an insect that had caused considerable injury to the roots of his arborvitae plants. An investigation on May 5 revealed the existence of a severe infestation of arval and pupal stages of two Rhynchophora species in the soil among the roots of the plants. After some of the specimens were reared to the adult stage most of the insects were found to belong to the genus *Phyllobius*, while a few were those of *Barypeithes pellucidus* Boh.

In corresponding with Mr. C. F. W. Muesebeck, and later with Mr. L. L. Buchanan, of the Division of Insect Identification, Bureau of Entomology and Plant Quarantine, it was learned that the *Phyllobius* species under consideration was not in the collection of the U. S. National Museum or in that of the British Museum. Mr. Buchanan advanced the possibility that the species might be of Asiatic origin or that it might be undescribed. At the present stage of investigation the specific name has not been determined.

The origin of the insect in Rhode Island is uncertain. One Middletown, Rhode Island, nurseryman has correspondence dated October 10, 1944 relative to the identification of the adult. Previous to that time no records concerning its existence in Rhode Island have been found.

The preliminary studies reported here are part of a research program initiated during 1947 to investigate the biology and control of the insect.

The eggs have not been collected in the field although several examinations have been made of the soil surrounding arborvitae roots in the area of infestation. Eggs have been recovered, however, in laboratory and greenhouse cages where female beetles were observed in oviposition. When newly laid, the eggs were smooth and white in color, elliptical in form with the sides almost parallel and the ends bluntly rounded. The average length of 42 newly deposited eggs was .6 mm. and the width .4 mm. After 48 hours the color changed from white to a light brown. Five days after deposition the average length of the egg increased to .72 mm. while the width decreased to .38 mm. Shortly before hatching, the tips of the mandibles of the larva, and in some cases larval movement, were visible through the egg covering.

When depositing eggs in laboratory and greenhouse cages the female beetles have been observed to insert the ovipositor into the soil to a depth of 2 to 3 millimeters. In most cases a single egg was deposited but occasionally 2, 3, 4 or 5 eggs have been observed to be deposited by a female in a particular spot.

Eggs kept in the laboratory in moist soil at 73 to 77° F. hatched in 10 to 11 days, while those maintained under similar conditions at temperatures above 80° F. failed to hatch although larval development was completed and larval movement within the egg covering was apparent within 10 days.

The newly hatched larva was observed to be white with a light yellowish-brown head capsule. A few hours after hatching, the larva was capable of fairly active movement, especially over the surface of the soil. In the field none of the earlier larval instars were found until October 6, 1947 when they were discovered feeding on the roots of pyramidal arborvitae along with larvae of *Brachyrhinus ovatus* and a *Barypeithes* species. At that time, the body of the *Phyllobius* larvae was a light pink while the head was brown in color.

On May 5, 1947 larvae and pupae of the *Phyllobius* species under consideration, as well as pupae of *Barypeithes pellucidus*, were found in the soil surrounding the roots of pyramidal arborvitae. At the time most of the *Phyllobius* species were in the pupal stage. Pupae of both species, brought into the laboratory and maintained at room temperature, emerged as adults within 72 hours. Newly emerged adults of *Phyllobius* were light brown in color; older ones are black, with the head, thorax and abdomen rather densely clothed with bluish-green scales. The adults are winged but were rarely seen in flight, particularly after late May.

In the field a few *Phyllobius* adults appeared during mid-May, 1947 and by May 26, all had emerged from the soil. On the other hand, adults of *Barypeithes pellucidus* emerged from the soil at the same time as those of the *Phyllobius* species but were not collected on arborvitae or any of the plants listed in tables 1 and 2 in diurnal collecting during the remainder of the season.

Both sexes were present in the field. Mating was first observed on May 24, and on July 16, the last date on which weevils could be found, mating pairs were collected. In the laboratory individual pairs were found to mate several times.

On arborvitae in the field, adults were found to feed in sunlight or shade, usually in the top third of the host plant. Newly formed leaves, generally at the terminal end of branches were preferred. A slightly irregular, cup-shaped area about a millimeter in diameter was eaten from the leaves. After a few days the tissue surrounding the consumed area became necrotic. This condition, together with the visible evidence of an irregular cup-shaped depression, was characteristic of the feeding injury produced by the *Phyllobius* species under consideration. During the night the weevils remained on the foliage but it was not determined whether feeding was carried on then.

When disturbed, the weevils dropped very readily to the ground where they remained immobile for a short period of time, but they did not feign death. Oftentimes when the weevils dropped from the foliage to the ground the wings were observed to become slightly extended. None, however, was observed to take wing when falling a distance of 7 feet.

At the present stage of the investigation it appears that the adult is not highly migratory. The presence of the larval and pupal stages in balled nursery stock indicates the most likely manner in which the insect is disseminated. Adult *Phyllobis* have been collected from Middletown and South Kingstown, Rhode Island, principally from arborvitae in nursery plantings. Larval *Phyllobius* have been found in the soil among the roots of pyramidal arborvitae at Middletown.

In table 1 are listed the host plants from which weevils of the *Phyllobius* species have been collected, and in table 2, those on which no weevils could be found, although in many cases the latter plants were in nursery rows adjoining heavily infested arborvitae. All host plant records were obtained on May 31 and June 16 from two nurseries located at Middletown, in the center of the *Phyllo-*

Eastern Branch Program.

[1] Contribution No. 710 from the Rhode Island Agricultural Experiment Station, Kingston, R. I.

Table 1.—Plants from which *Phyllobius* adults were collected, Middletown, R. I., May–June, 1947.

Slender Hinoki cypress	*Chamaecyparis obtusa gracilis*
Golden Sawara retinospora	*C. pisifera aurea*
Plume retinospora	*C. pisifera plumosa*
Goldenplume retinospora	*C. pisifera plumosa aurea*
Juniper	*Juniperus excelsa stricta*
Keteleer redcedar	*J. virginianna ketdeeri*
American arborvitae	*Thuja occidentalis*
New dark American arborvitae	*T. occidentalis nigra*
Pyramidal arborvitae	*T. occidentalis fastigiata*
Rosenthal arborvitae	*T. occidentalis rosenthalii*
Spiral arborvitae	*T. occidentalis spiralis*
Siberian arborvitae	*T. occidentalis robusta*
Berckman's golden arborvitae	*T. orientalis aurea*
Yellow golden arborvitae	*T. orientalis elegantissima*

bius infested area. Approximately 350 acres of nursery stock are included in the two nurseries.

From tables 1 and 2 it is evident that *Phyllobius* adults were collected only from the tribe *Cupresseae*, which includes the genera *Chamaecyparis*, *Thuja*, and *Juniperus*, while no adults were collected from the genera *Pinus*, *Picea*, *Abies*, and *Tsuga*, all of which are members of the family *Pinaceae*. Moreover, weevils were not collected from the deciduous plants recorded in table 2. *Phyllobius* adults were more abundant on varieties of *Chamaecyparis obtusa* and *Thuja occidentalis* than on species of *Juniperus* or varieties of *Thuja orientalis*. There was a marked difference in the degree of infestation between the species of *Thuja*, *T. occidentalis* varieties being heavily infested, while varieties of *T. orientalis* showed only a few weevils.

Table 2.—Plants from which no *Phyllobius* adults could be collected. Middletown, R. I., May–June, 1947.

Mugho pine	*Pinus mugo mughus*
White spruce	*Picea glauca*
Koster bluespruce	*Picea pungens argentea*
Spanish fir	*Abies pinsapo*
Canadian hemlock	*Tsuga canadensis*
Japanese yew	*Taxus cuspidata*
Boxwood	*Buxus sempervirens*
Flowering dogwood	*Cornus florida*
Japanese barberry	*Berberis thunbergii*

To date only the adult stage of the *Phyllobius* species has been used in control studies, which were conducted in the field during May and June 1947, at Middletown, Rhode Island.

Materials applied as sprays were DDT, benzene hexachloride (6% gamma isomer and 44% other isomers of hexachlorocyclohexane), and acid lead arsenate.

An arborvitae planting, variety *Thuja occidentalis fastigiata*, heavily infested with *Phyllobius* adults was selected for the insecticide trials. The planting consisted of 56 rows, each 390 feet long, containing plants 5 to 6 feet tall. Sufficient of the planting was utilized to provide three randomized, replicated plots of four 200-foot rows, three feet apart, for each insecticide treatment and for the check treatment. Approximately 350 plants were included in each replicate of every treatment.

On May 27, 1947, just before the spray materials were applied the number of weevils in 30 plants selected at random in the experimental area was obtained by placing a white cloth under each plant and shaking it gently. A total of 927 weevils was found on the 30 plants. After each plant was shaken, the date and the number of weevils found was written on a paper tag afixed to the terminal twig. The same procedure was followed 2 and 17 days after the sprays were applied except that 10 plants in the middle two rows of each replicate of each treatment were shaken, and the information on the paper tags included the date, number of the plant, treatment, replicate, and number of weevils obtained. None of the 30 plants from which weevils were shaken just previous to the application of the sprays was included in the plants shaken after the insecticide tests were made.

On May 27, a single nozzle orchard spray gun and 200 feet of hose was used to apply the sprays at a pressure of about 450 lbs. per square inch at the pump. A fine spray was used and each plant was covered thoroughly.

Table 3.—Control of the *Phyllobuis* weevil with materials indicated, Middletown, R. I., May–June, 1947.

Material	Amt. per 100 Gal. Water	Reduction in *Phyllobius* Weevil After: 2 Days	17 Days
	lb.	*per cent*	*per cent*
Lead arsenate	3	31.7	88.0
Benzene hexachloride 50% W	2	98.0	97.5
DDT 50% W	2	99.8	100.0
Check		2.4[1]	82.3

[1] Denotes increase rather than reduction.

In table 3 are shown the results obtained by applying lead arsenate, benzene hexachloride, and DDT as sprays to the foliage of pyramidal arborvitae for control of the *Phyllobius* weevil. It is evident that 2 pounds of either 50 per cent wettable DDT or 50 per cent wettable benzene hexachloride (containing 6 per cent gamma isomer) in 100 gallons of water were equally effective in controlling the insect. Three pounds of lead arsenate in 100 gallons of water was ineffective. The reduction of 82.3 per cent in the check treatment after 17 days was attributed to natural mortality, since at that time the weevil had become less abundant throughout the infested area.

SUMMARY.—The presence of an undetermined *Phyllobius* species as a new pest of nursery stock in Rhode Island is reported. The adult stage, which was present in the field from mid-May to mid-July, 1947, was collected from several species of the genera *Thuja*, *Chamaecyparis*, and *Juniperus* and was found most numerous on varieties of *Thuja occidentalis* and *Chamaecyparis obtusa*. Preliminary studies on the biology of the *Phyllobius* species revealed that the eggs were deposited in the soil to a depth of two to three millimeters and that the larvae fed upon the roots of pyramidal arborvitae. Control studies showed that DDT and benzene hexachloride were effective, while lead arsenate was ineffective in controlling the adult.

Toxicity to House Flies of Three Phosphorus Acid Esters

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Recent interest in hexaethyl tetraphosphate as an insecticide led to a study by Ludvik & Decker (1947) of the toxicity to aphids of a large number of phosphorus acid esters. The effectiveness of three of these esthers—hexaethyl tetraphosphate, tetraethyl pyrophosphate, and 0,0-diethyl 0-*p*-nitrophenyl thiophosphate—when applied as space sprays against house flies, *Musca domestica* L., has been investigated at the Agricultural Research Center at Beltsville, Md.

Hexaethyl tetraphosphate was shown by Hall (1945) to be contained in a contact insecticide developed in Germany. More recently Hall & Jacobson (1947) have shown that this product contains tetraethyl pyrophosphate. 0,0-diethyl 0-*p*-nitrophenyl thiophosphate, which was also used as an insecticide in Germany, has been described by Thurston (1946). (Now known as parathion.)

The hexaethyl tetraphosphate used in the tests conducted at Beltsville was prepared by the Schrader (1943) process, and the tetraethyl pyrophosphate by a modification of the same process. All the materials were of technical grade.

The tests of Ludvik & Decker indicate tetraethyl pyrophosphate to be about three times as toxic to the aphid *Myzus porosus* Sanderson as is hexaethyl tetraphosphate.

The comparisons in this study are based on measurements of toxicity to adult house flies as determined by the Campbell turntable method. The flies were reared by standard procedure. Preliminary tests were made to find the concentrations of each material required to give mortalities at several levels. Because of the low solubility of some of the phosphates in kerosene, the usual solvent for this method, a 1:1 mixture of acetone and refined kerosene was used throughout the tests. Because of the instability of both hexaethyl tetraphosphate and tetraethyl pyrophosphate in the presence of water, the acetone was dried before use and the sprays were prepared just before they were tested.

Mortality percentages were determined in four or six replications at each concentration, approximately 100 flies being used in each test. Tests were also made with the usual standard, the mixture of pyrethrins obtained from kerosene extract of pyrethrum flowers, the sprays being prepared with the same acetone-kerosene carrier. The results are given in table 1. To obtain the concentrations causing 50 per cent mortality, the results were plotted on log probability paper and these values obtained from the fitted lines.

Knock-down of flies is not given, because acetone greatly increases this measurement. This solvent when sprayed alone under the conditions of this method does not cause death. When used in conjunction with pyrethrins, however, it does increase mortalities. The phosphozus acid esters have not been studied in this respect, primarily because of their slight solubility in kerosene. Therefore, direct comparison of these esters had best be made, not with the common standard, but among themselves, as has been done in table 1.

CONCLUSIONS.—When technical-grade materials were used, tetraethyl pyrophosphate was found to be 5 to 6 times and 0,0-diethyl 0-*p*-nitrophenyl thiophosphate about 17 times as toxic to houseflies as was hexaethyl tetraphosphate. Under the conditions of these tests the three phosphorus acid esters were considerably more toxic than the pyrethrins. The least effective one, hexaethyl tetraphosphate, was about twice as toxic as the pyrethrins.

Eastern Branch Program.

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Table 1.—Toxicity to adult house flies of three phosphorus acid esters when applied in 1:1 acetone-kerosene sprays.

MATERIAL	CONCENTRATION	MEAN MORTALITY IN 1 DAY	MEAN CONCENTRATION CAUSING 50% MORTALITY	RELATIVE TOXICITY AT 50% MORTALITY LEVEL
	Mg./ml.	*Per Cent*	*Mg./ml.*	
Hexaethyl tetraphosphate	0.64	58	0.52 ±0.05	1
	.32	33		
	.16	3		
Tetraethyl pyrophosphate	.30	100	.095± .010	5.5 ±0.7
	.15	70		
	.074	43		
	.037	10		
Parathion	.079	100	.030± .003	17 ±2
	.039	71		
	.026	47		
	.020	11		
Pyrethrins (standard)	2	70	1.20 ± .14	0.43± .06
	1	45		

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Control of Pickleworms on Cucumbers and Cantaloupes

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The pickleworm, *Diaphania nitidalis* (Stoll), is an important limiting factor in the production of late cucumbers and cantaloupes in this area. Since no practical insecticide control measures had been developed, the standard recommendation in this area has been to plant early so as to harvest the crop before the middle of August. Cucumbers and cantaloupes maturing in this area after this time are usually completely destroyed by pickleworms.

In field size tests on cantaloupes in 1946 (Brooks & Anderson 1947) benzene hexachloride dusts were found to give excellent control of the worms but caused some foliage injury. Also DDT dusts were found to be fairly effective.

In view of these facts it seemed advisable to test these materials again in 1947. Another new insecticide dichlorodiphenyldichloroethane[1] was included in the tests.

METHODS.—Three rows each of Burpee Hybrid cucumbers and Smith's Perfection cantaloupes were planted on August 2, 1947. The rows were 5 feet wide and 120 feet long with two plants per hill. The hills were 3 feet apart in the row. Six hill plats replicated 3 times were used for each treatment. All dust treatments were made with a rotary hand powered duster at the rate of 40 pounds of dust per acre per application. Both the cucumbers and cantaloupes were dusted with a copper dust for downy mildew control on August 20, 25, September 12 and 18. The cantaloupes received an additional copper treatment September 26. All plants were treated August 2 for cucumber beetle control, using a 1-per cent DDT-2-per cent oil-impregnated dust. This treatment may have retarded the cucumber plants slightly for a few days, but gave perfect control of the striped cucumber beetle.

Insecticide applications for pickleworm control were made on the cucumber plants when they were setting fruit on September 12, and again at the first harvest time on Setember 18. The cantaloupes were treated on September 12, 18 and October 26. Cucumbers were harvested from September 18 to October 10. The cantaloupes were a late maturing variety and were defoliated by frost just as the first few melons were ripening. All plant growth was retarded during the greater part of August due to drouth. Normal rainfall occurred during the remainder of the season and the plants made a good growth, completely covering the ground between hills and rows.

Records were taken on the cucumbers by weighing and by examining all fruits for pickleworms at harvest time. The cantaloupes were not picked, but were examined on the vines for pickleworms on October 6 and 27.

RESULTS.—The materials used and the results obtained are given in table 1. As may be seen by these results, all treatments gave highly significant reductions in pickleworm damage on both cucumbers and cantaloupes. The untreated cucumbers showed 80 per cent wormy fruit as compared to less than 3 per cent wormy fruit for the different DDT, benzene hexachloride and (dichlorodiphenyldichloroethane) treatments with no significant difference. The number of marketable fruits from the check was 27 as compared to 89 to 109 from the different treatments. It is interesting to note that there were no significant differences in the number of fruits from any of the treated or untreated plants. However, the size of the fruits from the 1 per cent gamma benzene hexachloride treated area was significantly smaller than that from any of the other treated and untreated plants. This may be accounted for by the fact that the foliage on these treated plants was definitely chlorotic and somewhat burned. Slight foliage injury occurred on the 0.5 per cent gamma benzene hexachloride treated plants. No injury was observed on any of the other treated plants.

On October 6 all treated cantaloupes had less than 3 per cent wormy melons with no significant

[a] Eastern Branch Program.
[1] Dichloro diphenyl dichloroethane.

Table 1.—Pickleworm control on cucumbers and cantaloupes.

Dust Materials Used[1]	Cucumbers					Cantaloupes	
	No. Examined	Wormy		No. Marketable	Av. Wt., Oz.	Per Cent Wormy Melons	
		No.	Per Cent			10/6	10/27
1% DDT-2% Oil	216	1	.5	94	5.9	0	7
3% DDT	217	5	2.3	109	6.1	1	8
5% DDD	232	5	2.2	102	6.7	3	2
0.5% γ benzene hexachloride	197	6	3.0	92	5.6	3	18
1% γ benzene hexachloride	201	1	.5	89	4.2	3	19
Untreated Check	204	163	80.0	27	6.1	52	65
Difference required for significance (19–1)	NOT sig.	63	—	52	1.1	—	—

[1] All materials applied at 40 lbs. per acre. Cucumbers treated September 12 and 18, harvested September 18 to October 10. Cantaloupes treated September 12, 18 and 26.

differences between treatments. The untreated cantaloupes had 52 per cent wormy fruit. By October 27 the DDD and DDT treated cantaloupes were still relatively free of worms having only 2 and 8 per cent wormy melons, respectively. However, the benzene hexachloride-treated melons had significantly more injury with 18 to 19 per cent wormy fruits. The untreated cantaloupes had increased to 65 per cent wormy melons.

SUMMARY.—In these tests 1 and 3 per cent DDT and 5 per cent DDD dusts gave excellent pickleworm control on cucumbers and cantaloupes with out injury to the plants. Benzene hexachloride 0.5 and 1 per cent gamma isomer dusts also gave excellent control but caused some foliage injury on the cucumber plants.

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Biological Studies on the Horse Flies of New York

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Horse flies probably are the most injurious blood-sucking pests of cattle in New York. It is estimated that they bring greater losses to dairymen than the combined effects of the horn flies and stable flies, and they probably are more important pests in New York than the cattle lice.

Dairy losses attributable to Tabanidae are principally due to the attacks of *Tabanus vicarius*, Wiedemann, *T. lasiophthalmus*, Macquart, and to a lesser degree, of *Chrysops vittata* Wied. *Tabanus lasiophthalmus* begins emerging in May and persists until early July. *Tabanus vicarius* makes its appearance in June and is present in numbers until the latter part of August. While most abundant in July, *C. vittata* is in the field from June to September and has the longest season of activity among the New York species.

So far as horse fly biologies are known the majority of the species spend the immature stages in mud, water, algae, or other aquatic or semi-aquatic habitats. Since these stages of *Tabanus lasiophthalmus* and *T. vicarius* have never been found in such places, students of the group have frequently suggested that they must be scattered widely in pastures, meadows and other farm lands. Previous investigators have found a total of about half a dozen larvae of *T. vicarius* none of which were in notably moist situations. The finding of one egg mass of *T. lasiophthalmus*, and none of *T. vicarius* is reported in the literature.

The writers have been able to show beyond reasonable doubt that *Tabanus vicarius* can grow to maturity and emerge in pastures and meadows and that in New York these places form the normal habitat. Quantitative collections of larvae were made by drying sections of sod on wire racks suspended over pans of water. As the sod dried the larvae dropped out into the pans. This method showed the presence of as many as one larva for each 2 square feet of sod in many areas. Since laboratory rearing has established a 1 to 1 sex ratio for this species, these collections indicate that 10,000 females can be produced by an acre of pasture. In addition to these larval collections, night sweepings in meadows during the season of emergence have yielded 5 to 15 adults of *T. vicarius* for each 100 strokes of the net. The adults thus caught showed a sex ratio comparable to that obtained in laboratory rearing and many individuals were obviously teneral indicating emergence in the immediate vicinity. Finally in 1946 several thousand eggs deposited in laboratory cages by field-collected females were placed in a 400-square-foot area of sod surrounded by a sheet iron barrier extending 1 foot above ground and about 18 inches below. During the following 12 months the caged area suffered the usual extremes of northern New York climate, among them partial drought in late summer and total submergence for several days in the spring. Examination of the plot during the *T. vicarius* emergence season in 1947 showed that larvae of several sizes were numerous. The plot was covered with aster cloth at this time and a number of flies caught. It is expected that larger numbers will emerge in 1948 since laboratory rearing has shown that over 90 per cent of the individuals have a 2-year cycle. Of 115 flies reared from egg to adult in the laboratory only 10 emerged within approximately a year after hatching, the remainder requiring 2 years to complete the cycle.

While it has been presumed that *Tabanus lasiophthalmus* spends its immature life in habitats similar to those occupied by *T. vicarius*, the writers have been unable to make quantitative collections of its immature stages with the methods used in taking *T. vicarius* larvae. One egg mass was obtained from a caged female and 40 of the larvae from this mass were fed in individual cages. Eight of them produced adults after 10 to 11 months. The pupal period had a duration of 11 to 15 days.

Chrysops vittata was reared from egg to adult by keeping the larvae in mud from the natural habitat where the eggs were obtained, and feeding them on larvae of several small species of crane flies, or on blow fly maggots. The mud was heated sufficiently to kill all arthropod life, then placed in large shallow pans and remoistened. The pans were slightly elevated at one end so that a moisture gradient ranging from moist mud from which water could not be expressed, to complete submergence, was obtained. Several field-collected egg masses were allowed to hatch in each pan and crane fly larvae from the natural habitat added at intervals. *Chrysops vittata* larvae had previously been observed feeding on small crane fly larvae in smaller jelly glass cages. When crane fly larvae were no longer available in sufficient quantity newly hatched blow fly maggots of several species were found equally acceptable to the *Chrysops* larvae. As the *Chrysops* larvae increased in size larger maggots were fed. There was little or no evidence of cannibalism among the *Chrysops* larvae, and the maggots apparently never were predatory. The *Chrysops* eggs placed in these pans hatched during the period of July 7 to 10, 1946. The first adult emerged June 30, 1947. Examination of the mud immediately after the first fly emerged revealed the presence of 193 full-grown larvae and 42 pupae. All of these were placed in individual containers and from them 132 adults, 59 males and 73 females, emerged during the period from June 30 to August 18. In general, emergence was slightly later than that occurring in the field.

Eastern Branch Program.

[1] The senior author is now an entomologist for the Food and Agriculture Organization of the United Nations.

Practical measures for the control of horse flies have never been evolved and there seems to be little prospect of great progress in the near future. The foregoing data on the larval habitat, and place of emergence of *Tabanus vicarius* might suggest treatments to be applied to pastures and meadows with the expectation of killing many of the emerging horseflies, and at the same time benefiting the pasture by controlling some of the forage pests. This might be done on a practical basis if it were not for the residue problem, though there probably would be more benefit from the increased hay yield than from such horse fly control as might be obtained. In dairy farming areas large acreages would have to be covered. Weathering, the rapid growth of forage plants, (and the fact that it is cut long before all horseflies have emerged) would make it necessary to apply several treatments during a season.

Amount of Dew Found on Leaf Surfaces

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The amount of dew that may form on plants is of importance in application of dusts or sprays. To find some information on this subject, the following observations were made. Steel triangles, each containing about 35 sq. cm., were exposed to the air on the night of May 3. The following morning it was observed that moisture was present on both sides of the metal piece and it appeared that the upper surface had a heavier deposit of dew than the under side. The triangles were weighed to determine the amount of water, and it was found that the dew amount to 55 gallons of water per acre.

On the morning of May 25, cabbage was observed to have a very heavy load of moisture on the leaves. This was measured by taking small sections (3×3 cm.) of blotter, and placing the paper upon the leaves. The gain in weight showed that dew was present on the leaves at the rate of about 325 gallons per acre. This is an excessive amount as the dew on cabbage tends to collect in large drops; nevertheless, it shows that a large amount of water is present. Some of this moisture may be due to guttation.

Bean foliage was similarly measured on August 11. Both sides of the leaves were tested and it was found that the top of the leaf had 84 gallons per acre, and the bottom had 72 gallons. The dew on both sides was evenly distributed, not in large drops as on cabbage. Previous work (Stanley, 1945) shows that beans may have 10.2 acres of foliage per acre of ground surface. Thus, 1591 gallons of water may be present on the bean foliage per acre of ground surface. This is equivalent to about .08 inch of rainfall.

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Book Reviews

METHODS OF INSECT CONTROL, PART 1. By Dwight Isely. 134 pages, Burgess Publishing Co. 1946. PART 2, 184 pages, 1947.

Based on 30 years of experience in teaching and research this book departs from standard text book form in two important respects.

The first of these departures is that it represents an analysis of the fundamental reasons why various methods of insect control are effective. This study of reasons for effectiveness makes possible the grouping of the procedures for control of many insects. In this way it attempts to organize our knowledge of insect control and place it on a logical basis. It makes no attempt at a listing of insect pests of various crops and recommended control measures as must be done in a handbook.

The other characteristic is that the various procedures in control are studied by a case method. In this way it avoids one of the problems of teaching entomology which results from the vast number of species of destructive insects to be considered. Here a relatively small number of species are used as types representative of groups susceptible to certain control programs. By thus reducing the number of species studied a more careful analysis of each problem is possible.

While designed as a text for a second course in entomology this book is so readable, and so full of concise information that it will be found of high interest to all who are working in the broad field of economic entomology. The insect biologist will also find much useful material in the author's treatment of type insects. There is a summary and a list of references following the discussion of each type of control.

The general effectiveness of the material in this book was well demonstrated two years ago when Professor Isely was invited to give a series of lectures on cotton and rice insects to the graduate student and staff group at Cornell. Much of the subject matter presented was from the manuscript of these volumes.—H. H. SCHWARDT.

CHEMICAL INSECT ATTRACTANTS AND REPELLENTS. By Vincent G. Dethier. 289 pp., 62 Figures, 39 Tables. The Blakiston Company, Philadelphia, Pennsylvania.

This book will be welcomed by those interested in insect attractants and repellents. The role played by chemicals in attracting and repelling insects is of vast economic importance, and is a subject that has long been in need of critical analysis and is deserving of expanded research. Dr. Dethier, in this book, has made a serious attempt, and a good one, to bring together and organize the fundamental aspects of the subject. The book provides a background that will open new vistas for future investigation on this important subject. It will provide students and workers with a clearer insight to many of the factors involved in the study of a most complex field, and thereby give impetus to better research.

Dr. Dethier has done an excellent job of assembling and assaying important but scattered literature. The book portrays, in understandable manner, many chemical, physical, physiological and botanical problems essential in evaluating an important but undeveloped subject.

The book is an outstanding contribution to the subject of insect attractants and repellents. It will be an asset to teachers, students and research workers in Entomology and related sciences.—GEORGE S. LANGFORD.

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Insecticide Programs and Biological Control in South Africa

For several years past, workers in South Africa have been interested in the effect of insecticide schedules on the natural control of pest insects and upon biological control operations. It had become very evident that biological control could not exist side by side with the recognized methods and practice of chemical control. The former would have little chance of becoming the permanently useful adjunct to pest control that it was hoped. Investigations designed to throw light on the problem of combining two such seemingly incompatible methods were commenced by the author and were continued by him and other workers for a number of years.

It was evident that in order to understand the problems involved it was necessary to obtain information relating to population fluctuations and their causes under field conditions over as long a period of time as was possible. The insect chosen for this study was the common cabbage moth, *Plutella maculipennis*, which, in the Pretoria area where the writer was stationed, breeds actively throughout the year. Since its natural enemies are also active at all times, it was possible to follow an uninterrupted programme of population records and to study the mortality factors over a period of years. The full results of this study have now been published and it is not proposed to deal in any detail with them here. Briefly, three main conclusions can be drawn as far as the present subject is concerned.

In the first place, it was clearly demonstrated that the application of an insecticide without due regard to events in the population of insects concerned can be the direct cause of an outbreak of the insect later in its history together with a comparable increase in the damage to the crop. This almost invariably follows on the normal insecticide practice of applying the poison at or near the peak of abundance of the pest. This type of treatment is incompatible with the maintenance of any balance between the pest and its natural enemies and can only lead to ever-increasing use of chemical control measures.

Secondly, it was shown that, by correct timing of the application of an insecticide, based upon events in the population of the insect, it was possible to afford a measure of protection to the crop during a critical period while, at the same time, retaining conditions which made it possible for natural control to become established. The cabbage plant is most susceptible to the attack of *Plutella* during the first three weeks after planting out from the seedbed. During this period, a comparatively small population of larvae can do a very considerable amount of harm. Protection at this time can be accomplished by treating the young seedlings with an efficient insecticide as they are removed from the seedbed and hence by planting out a virtually clean plant. The protection from damage thus afforded lasts about three weeks, *i.e.*, for the duration of the most susceptible period for the plant and, since migration of both moths and natural enemies into the newly-planted crop takes place gradually during this time, a natural balance tends to be built up as time goes on. Normally, no further treatment of the crop is necessary. Thus, an insecticide can be used to protect a crop at a critical period without seriously disrupting natural control provided that it is used at the right time.

Perhaps the most important disclosure from these investigations, however, was the strong emphasis laid upon the necessity for regarding the plant as an ecological unit when planning control measures of any kind. It is only by studying the plant in relation to the various different insect species inhabiting it and by treating this biological complex as a whole that

we can expect to obtain rational methods of treatment and a control which can be regarded as satisfactory from every point of view. The various species of insects and their respective natural enemies occurring on one and the same plant are often very closely interrelated so that the efficient control of one pest species may profoundly influence the population of the co-existing species. In our case, the *Plutella* populations and the populations of cabbage aphids shared many predators in common. When aphid populations were rigorously controlled, many of these predators were no longer attracted to the plant since they were primarily aphid feeders. The control of *Plutella* by this group therefore decreased noticeably. In order to provide means of attraction for these insects therefore it would seem advisable to leave small, subeconomic infestations of aphids on the plants. In other words, our control of aphid populations should be carefully regulated and it should no longer be the aim to obtain as near 100 per cent kill as has been the case heretofore.

Another investigation which has given every promise of a successful outcome has been that of the Codling moth on deciduous fruit in the Cape Province area. In South Africa, as elsewhere in the world, Codling has been getting steadily worse in spite of increasing spray schedules and the use of newer and more efficient insecticides. One by one, the latter have first of all given an increased control and have then gone the way of the old lead arsenate programme. Our Codling has two full and one partial generations during the season. During the first of these, *i.e.*, during early spring after blossom fall, parasites and predators are very scarce. The egg parasite *Trichogramma*, in particular has not yet fully changed over from its alternate hosts to codling and larval parasites are virtually non-existent. During the second generation, however, the picture has changed and, in orchards which are not sprayed, parasites and predators are plentiful. It seemed logical to assume that, if the codling could be controlled satisfactorily during the first generation, then parasites and other natural enemies might be able to take care of the situation for the remainder of the season.

At the author's suggestion the entomological staff of the Fruit Research Station at Stellenbosch in the Cape undertook an investigation into the possibility of using such a combined insecticide-parasite programme. It was evident that some host population would need to be left in order to provide a nucleus for the breeding up of the parasites during the early stages of the second generation. The control during the first brood would therefore not have to be too efficient. It was considered possible to do this without great difficulty. I do not propose to go into detail regarding the actual work done but may say that it entailed the use of imported parasites as well as the encouragement of indigenous ones. The outcome to date has been distinctly promising. Under the programme, *Ephialtes caudatus*, which had been introduced into the area some 27 years ago and was thought not to have been established, suddenly appeared and increased rapidly without further liberation. *Ascogaster*, which had also been introduced several years ago and was present in very small numbers in the orchards, increased by leaps and bounds. Indigenous parasites also increased markedly and performed very useful work. Total control by natural enemies during the 2nd generation was high. But the main result was that a very satisfactory overall control of codling was resulting from the combined programme—results equal in many cases to those obtained under the best spray schedule conditions.

Just before I left South Africa, I was told that, during last season, the Cape workers had obtained excellent results once again. There were exceptions, however, and these were in orchards where the first brood had been controlled too severely by the insecticide. The great advantage of such a combined programme in the control of pest insects like codling is very obvious. Not only are the problems connected with the progressive failure of insecticides in a fair way to becoming solved, but the cost of control measures is being very considerably reduced.

At the same time, I feel that we should be careful about the type of insecticide used in such a programme. A substance with any appreciable residual effect is to be avoided. Also, as in the case of *Plutella* mentioned earlier, other pests on the tree must be considered at the same time. We in South Africa are also familiar with the sudden increase in woolly aphis and red

spider following the use of such insecticides as DDT and benzenehexachloride. But the use of such powerful poisons is hardly likely to enter the combined programme in view of the difficulties connected with the necessity of leaving a certain proportion of the population of the host insect.

Exploration of the use of the combined method has also commenced in the case of scale insects on citrus. These investigations, however, are in too early a stage for me to be able to say anything about them. Here we have a situation in which it is possible to have perfect natural control established in an orchard but in which there is always the danger of a sudden breakdown in control for some reason or another. It therefore becomes necessary to study the factors involved so that some insecticidal procedure may be taken at the appropriate time in order to prevent a sudden, rapid and possibly fatal outbreak of the scale.

In all this work we have been faced with the outstanding fact that pest populations have been increasing in an alarming measure in spite of more and more efficient and stringent methods of control. I should perhaps say that it is *because* of this increase in the use of insecticides that our problems have arisen. A return to natural methods seems to promise greater chances of success than a continuance of the present way of meeting the situation. Since natural factors are liable to fluctuations from causes outside our control, it seems necessary to have supplementary methods for use at special times, *i.e.*, in emergencies. In the main, the use of such measures will be indicated by a properly conducted study of the problem.

I feel confident that, with further investigation into specific cases, this method of combining insecticidal treatment with biological control in a rational manner will prove to have a very wide application and will eventually prove to be one of the main methods of combatting pest insects. It is realized that biological control cannot always give a satisfactory economic control of a pest when used alone. It is also felt that insecticides often provide a very unsatisfactory answer to some of our major problems. Perhaps in a combination of the two methods, scientifically compounded, we have something approaching the ideal method of pest control.

G. C. ULLYETT
Imperial Bureau of Biological Control

A.I.F. ASSOCIATION COMPILING FACTS ON NEW ORGANICS

A compilation of all factual information now available on the new organic insecticides and fungicides is being undertaken by the Agricultural Insecticide & Fungicide Association in cooperation with committees representing manufacturers, food processors, federal and state agencies, and other interested groups.

Entomologists are in an especially advantageous position to help in compiling this factual information, and, since the assembled data will be available to all cooperating groups, as well as public information outlets, all scientists will benefit from the free exchange of such data.

That this factual information is needed can be seen in the discussions and unfavorable press comment of recent months, involving federal and state agencies, and the industry. These reports indicate a definite lack of scientific knowledge of the problems involved, or at best a lack of coordinated information.

Specific studies on each product will be made by special committees, being established by the A.I.F. Since the Association membership represents practically all of the basic producers of the chemicals involved, much additional data can be made available.

To compile information which is now widely scattered, all the groups have been asked to furnish data on several aspects of the problem, including:

The amount of residue of each insecticide presen at harvest time on various crops under recom mended applications.

Known methods of residue removal for each chemical, or report of experimental data to date.

Information on the actual toxicity of each product to warm-blooded animals, including man, and particularly information concerning the effect of the residues which persist on the crop at the time it is harvested.

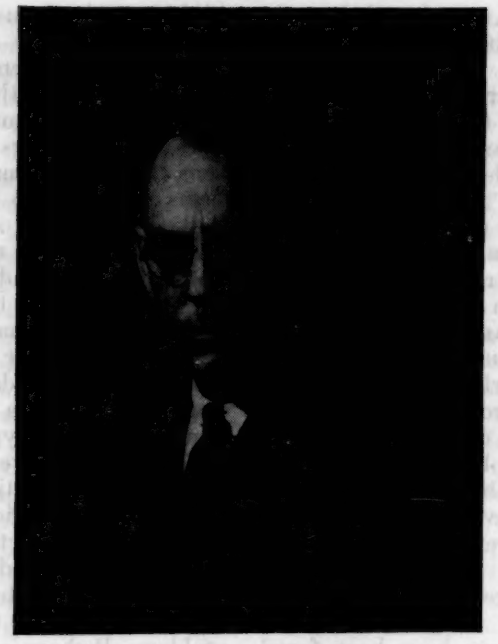
Methods of analysis and analytical methods for determining minute quantities in food products.

Hazards to the users and other pertinent information of this type.

We are asking your cooperation in making available to us any data which you have on the above subjects. We would also be glad to have your comments and suggestions on the program, and any information as to what you are planning on such type of work. We in turn will be glad to exchange with you the results of our compilation.

We would greatly appreciate it if you would send such information to the attention of Dr. Charles L. Smith, A.I.F. Technical Adviser, 285 Madison Avenue, New York 17, New York, who will direct the compilation and use of the technical material. Full credit will be given to the source of all data supplied.

L. S. HITCHNER, *Executive Secretary, Agricultural Insecticide and Fungicide Association*



RAY TRASK WEBBER

OBITUARY

Ray Trask Webber, 1884-1948

Ray Trask Webber died suddenly at his home in Beverly, Massachusetts at noon on February 13, 1948. His death was due to a severe heart attack following a year or more of ill health. He is survived by his wife, now of Ogdensburg, New York, and a sister and brother in Beverly. Mr. Webber was born in Beverly September 14, 1884. He began work with the, then, Bureau of Entomology, U. S. Department of Agriculture, March 12, 1912, at the Gypsy and Brown-tail Moth Parasite Laboratory at Melrose Highlands, Massachusetts.

While working in Melrose Highlands he supplemented his investigational work and formal education by taking extension courses in zoology at Harvard University. He was an enthusiastic worker with a keen interest in the biological control of injurious insects. His life history studies of native insects and their natural control, of parasitic insects and their host relationships, together with his excellent taxonomic work, particularly with Dipterous parasites, are important entomological contributions. His biological investigations contributed materially to the knowledge of insect behavior and were a substantial aid to other investigators in similar work. He spent parts of five years from 1923 to 1927, inclusive, in Europe and North Africa gathering and sending insect parasites of the gypsy moth, brown-tail moth and the satin moth to New England resulting in the establishment of several beneficial species. In 1928, Mr. Webber was transferred to the Division of Forest Insect Investigations and continued his work with Dipterous parasites of forest pests. In 1935 Mr. Webber was transferred to Morristown, New Jersey where he worked on the Dutch elm disease problem, investigating the role of the native and European elm bark beetles in the spread of the fungus causing the disease. While Mr. Webber's previous experience had been in the field of biological control, he soon demonstrated his ability in this new field of endeavor. Again in 1945 he transferred, this time to Columbus, Ohio and conducted investigations on possible insect vectors of a virus disease of elm, phloem necrosis. While at Columbus his health gradually failed and on January 31, 1947, after 35 years of Federal service he retired to his home in Beverly, Massachusetts.

Mr. Webber was a member of the American Association for the Advancement of Science, The American Association of Economic Entomologists and The Entomological Society of America.

Mr. Webber regained some strength during his year of retirement and several of his former associates had the privilege of renewing their visits with him and Mrs. Webber. He seemed much stronger early in February, 1948, and attended the meetings in Boston on February 11 of the Massachusetts Tree Wardens and Foresters Association and had planned to attend the meeting on February 12, but he was not able to and returned to his home on the morning of February 12.

During the meeting on February 11 many of his former associates had an opportunity to visit with him and they were shocked to learn of his sudden death a few days later. We who knew him will long cherish his fine friendship and memory.

S. S. CROSSMAN and D. E. PARKER

PROCEEDINGS OF THE NINETEENTH ANNUAL MEETING

EASTERN BRANCH, AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS,

Hotel Benjamin Franklin, Philadelphia, Pa. November 20 and 21, 1947

The Nineteenth Annual Meeting of the Eastern Branch, American Association of Economic Entomologists, was called to order by the Chairman, John O. Pepper, at 9:30 A.M., November 20, 1947, in the Crystal Ballroom of the Hotel Benjamin Franklin in Philadelphia. Doctor Pepper, assisted by Dr. C. M. Packard, Vice-Chairman, presided over the two-day session which was devoted to the presentation and discussion of 61 papers. Due to the heavy program each paper was limited to 10 minutes presentation time. With the cooperation of the speakers plus the efficient handling of the program by the Chairman, the program was completed by 5:30 on the afternoon of November 21st.

At the short business session at noon of November 20th, the Chairman appointed the following committees:

Nomination: H. G. Walker, F. M. Smith, L. A. Stearns, *Chairman*
Auditing: R. W. Leiby, Merrill M. Darley
Resolutions: F. W. Poos, W. S. Hough, L. D. Anderson, *Chairman*
Awards: T. Walter Reed, J. A. Cox, W. E. Fleming, *Chairman*

The Secretary-Treasurer made the following report, which was referred to the Auditing Committee.

REPORT OF THE SECRETARY-TREASURER

Notices of the Nineteenth Annual Meeting to be held in Philadelphia on November 20–21, 1947, were sent out to approximately 700 members of the American Association of Economic Entomologists residing in the eastern territory. A total of 61 paper titles were received which is approximately double the number received last year. Dues paying members for 1946–1947 totaled 246.

The eighth Annual Award for the most outstanding paper presented at the 1946 meeting went to Dr. R. W. Dean for his paper "Apple Maggot Control with DDT Sprays and Dusts," published in the April, 1947 issue of the Journal of Economic Entomology.

FINANCIAL STATEMENT

Balance on hand, November 15, 1946		$3,135.18
Receipts		
Dues for 1946–1947—November 1946 Meeting	$ 264.00	
Dues for 1947–1948	202.00	
Sale of *Entoma*	5.00	
Balance returned from W. Boyd—Postage	8.00	
Receipts from *Entoma*	3,259.43	
Total receipts	3,738.43	6,873.61
Disbursements		
Stark-Films (Projection Equipment)	50.00	
Payment to Secretary-Treasurer 1947	200.00	
Clerical Services		
Eastern Branch	64.65	
Entoma	669.96	
Postage and Stamped Envelopes		
Eastern Branch	86.00	
Entoma	285.00	
Expenses of Secretary-Treasurer at 1946 Meeting	23.64	
Entoma Committee Meeting Expenses —C. C. Hamilton	2.85	
Miscellaneous Telephone Calls	2.31	
Annual Award	75.00	
Engraving	2.15	
Printer		
Eastern Branch	33.35	
Entoma	2,133.50	
Total disbursements	$3,628.41	
Balance on hand, November 15, 1947		3,245.20
Distributed as follows:		
Checking Account, The Union National Bank and Trust Company, Mount Holly, N. J.	$3,318.60	
Less outstanding checks:		
11/6 Geo. S. Langford 50.00		
11/12 E. B. Fagan 33.40	83.40	
		$3,235.20
Cash on hand in office		10.00
		$3,245.20

BYRLEY F. DRIGGERS
Secretary-Treasurer

REPORT OF AUDITING COMMITTEE

November 21, 1947

Your Auditing Committee has examined the books and accounts of the Secretary-Treasurer and has found them to balance and to be in good order.

R. W. LEIBY
MERRILL M. DARLEY

REPORT OF EDITORIAL COMMITTEE OF *Entoma*

Doctor Langford, Editor of *Entoma*, reported that the seventh edition of *Entoma* was coming off the presses and all members of the Association should have copies in their hands by or shortly after the first of the year. A few advanced copies had been received and had been sent to the members of the Editorial Committee and officers of the Eastern Branch a few days before the November meeting. Doctor Langford submitted the following Summary and Preliminary Report on the Business Activities of *Entoma*.

SUMMARY AND PRELIMINARY REPORT
BUSINESS ACTIVITIES—7TH EDITION OF *Entoma*

Sales

Advertising paid	$6,666.05		
Advertising unpaid	2,345.00		
		$9,011.05	
Paid Listings—7th Edition		401.00	
Sales—6th and 7th Editions		392.20	
Gross business—Nov. 18, 1946 to Nov. 15, 1947			$9,804.25

Expenses

1. Stationery, circulars, etc.	57.50	
2. Clerical help	669.96	
3. Stamps	270.00	
4. Printing Seventh Edition of *Entoma*	6,000.00 (?)	
Total expenses		6,997.46 (?)
Net profit as of November 15, 1947		2,806.79 (?)

Estimated Earnings for 1947 Edition

1. Assets (estimated)			
a. Present estimated profit	$2,806.79		
b. Sales—3,000 copies	3,000.00		
		5,806.79	
2. Liabilities (estimated)			
a. Stamps for mailing	800.00		
b. Clerical help	350.00		
c. Advertising for sale of 3,000 copies	150.00		
d. Miscellaneous	150.00		
		1,450.00	
Estimated earnings			4,356.79

Status of Funds Received

1. Total funds received		$7,559.25
2. Distribution of funds		
a. Transferred to Eastern Branch	$3,000.00	
b. On deposit—Prince Georges Bank & Trust Company and cash	4,559.25	
		$7,559.25

11/15/47

REPORT OF COMMITTEE ON RESOLUTIONS

November 21, 1947

Your Committee desires to present the following resolutions:

(1) That the Secretary send letters of sympathy to the nearest relatives of Philip A. Readio and Vernon B. Haber who have passed away since our last meeting.

(2) That we favor an increase in annual dues of the parent association if this will accomplish prompt publication of the results of current research.

(3) That this organization extend its thanks to the management of the Benjamin Franklin Hotel and the Philadelphia Convention Bureau for their courtesies and facilities extended during the course of this meeting.

F. W. POOS
W. S. HOUGH
L. D. ANDERSON, *Chairman*

REPORT OF NOMINATING COMMITTEE

November 21, 1947

Your Committee proposes the following names as officers of the Eastern Branch of the American Association of Economic Entomologists for the coming year.

For Chairman: C. M. PACKARD
For Vice-Chairman: FRANKLIN C. NELSON
For Secretary-Treasurer (3 year term): B. F. DRIGGERS
Representative of A.A.E.E.-Eastern Branch on Committee to Popularize Entomology: W. E. BLAUVELT

H. G. WALKER
F. M. SMITH
L. A. STEARNS, *Chairman*

The reports of the various committees were approved and the Secretary was instructed to cast a

ballot for the officers nominated by the Committee. Mr. Packard, the incoming Chairman, was escorted to the Chair and took up the duties of Chairman.

Under New and Miscellaneous Business, Doctor Hamilton opened a discussion of finances. He suggested the possibility of a registration fee instead of membership dues. He also lauded Doctor Langford for his untiring efforts in serving as editor of *Entoma*. The suggestion was made that it might be advisable to set up and accumulate a fund so that in the future the editor of *Entoma* could deal with printers on a more business like basis. The question of the Annual Award was brought up and discussed thoroughly. Some questioned the advisability of continuing the award, raising the cash award, etc.

The various discussions led to the following motions made, seconded and duly passed.

(1) That a committee be appointed by the Chairman to study the question of the Annual Award and report at the next annual meeting.

(2) That a registration fee of $2.00 collected from all persons attending the meetings be substituted for the annual dues of $2.00, provided the motion was not in conflict with the Constitution. (This motion is not in accord with the Articles of Agreement governing the Eastern Branch (JOUR. ECON. ENT. *23:* 129, 1930) and apparently is out of order.) The dues for the Eastern Branch are fixed by Article 8 of the Agreement and any change in them must be made by amendment of the articles in the prescribed manner, which is governed by Article 7 which is as follows.

Article 7. All proposed alterations or amendments to this agreement shall be referred to a committee of three at a regular meeting and must be approved by the executive committee of the American Association of Economic Entomologists. After a report has been made by the committee, the alterations or amendments may be adopted by a two-thirds vote of the members present; provided, that a written notice of the proposed changes has been sent to every member of the Branch at least one month prior to the date of action.

(3) That the Committee on *Entoma* study the question of the handling of the finances of *Entoma* and the finances of the Association and report at the next meeting.

UNIT AWARD FOR SUPERIOR SERVICE, JAPANESE BEETLE LABORATORY, MOORESTOWN, N. J.

During the course of the meeting time was made available for the presentation of an award for superior service to the Japanese Beetle Laboratory workers. Undersecretary Dodd of the U. S. Department of Agriculture was present and made the award at which time he made the following comments.

"All of you are as familiar as I am with the work and accomplishments of the Bureau of Entomology and Plant Quarantine of the U. S. Department of Agriculture. You are, likewise, fully familiar with the work and accomplishments of its Japanese beetle laboratory at Moorestown, N. J. You know of the accomplishments of the workers of this laboratory in acquiring a detailed knowledge of the biology, habits, and distribution of the Japanese beetle, in studying and colonizing its insect enemies, and in developing insecticides for use in controlling the adult beetles on plants and other stages of the insect in the soil. As important as these accomplishments have been, the development and practical application of the idea of utilizing a disease organism as a method of control may surpass all other achievements. I refer to the development of methods of utilizing the organism that causes the milky disease of the grubs. Despite the fact that diseases have often been found attacking insects, and sometimes have been known to reduce populations from outbreak to insignificant proportions in a short time, the development of methods for their practical utilization is unique in the history of insect control. The success of this project, therefore, has not only given us a valuable means of dealing with the Japanese beetle but also provides a background of information and experience that may point the way to the practical utilization of diseases for the control of other insects.

"A few figures may serve to indicate the extent to which development of milky disease spore dust has been utilized. Since the first colonization of the milky disease in New Jersey in 1939, through September 1947, over 140,000 pounds of spore dust was processed at the Moorestown laboratory for its own use and that of cooperating State agencies, principally in Maryland, Connecticut, New York, Delaware, and Ohio. As of January 1, 1947, these agencies had treated over 82,000 sites, involving nearly 68,000 acres in 533 counties in 12 States and the District of Columbia. Many additional acres have been treated with spore dust produced and distributed by commercial processors. All available evidence indicates that this distribution of milky disease spore dust has been a valuable aid in bringing the Japanese beetle under control in the older infested area and in holding its increase in newer infested areas to a much lower level than would have occurred in its absence.

"For this outstanding accomplishment I am pleased to present to the Moorestown Laboratory the Department's Unit Award for Superior Service."

The following members and guests registered during the two day meeting.

Adams, J. Alfred
Adams, J. F.
Alexander, C. P.
Allen, H. W.
Anderson, Lauren
Anderson, M. L.
Arnold, Robert B.
Ashdown, Donald
Avens, A. W.
Badertscher, A. Edison
Baker, Howard
Barber, G. W.
Barthel, W. F.
Beacher, John P.
Beatie, Russell H.
Beinhart, E. G.
Berry, R. C.
Beard, R. L.
Bickley, W. E.
Bigger, J. H.
Bishopp, F. C.
Bissell, T. L.
Bissinger, W. E.
Bixby, A. F.
Blauvelt, W. E.
Bobb, M. L.
Boyd, Wm. M.
Brann, J. L.
Brannon, Lloyd W.
Brian, Chas.
Brooks, J. W.
Brunson, M. H.
Brunton, J. G.
Buchholz, A. B.
Buchholz, J. H.
Buettner, Wm. O.
Burgess, E. D.
Bussart, J. W.
Butler, Geo.
Cahill, Roger W.
Camson, E.
Cassaday, T. J.
Chamberlain, J. J.
Chapman, P. J.
Chisholm, R. D.
Clancy, D. W.
Clark, C. A.
Clark, Elton
Compton, C. C.
Connola, Donald P.
Cooker, J. F.
Coon, E. F.
Cory, Ernest
Cox, J. A.
Crissman, W.
Darley, M. M.
Dean, R. W.
Deuber, C. G.

Dewey, J. E.
Dickinson, Berton
Dietz, H. F.
Ditman, L. P.
Dobbins, T.
Doehlert, Chas.
Domnick, C. B.
Donelson, Loren
Donohoe, H. C.
Dove, W. E.
Doordon, John E.
Dutky, S. R.
Dye, H. W.
Earle, Hilton H., Jr.
Farr, N. W.
Farrar, M. D.
Fassig, W. W.
Ferguson, J. R.
Ferguson, Wm. C.
Filmer, Robert S.
Fleming, W. E.
Foster, R. D.
French, G. T.
Friend, R. B.
Fronk, W. D.
Frost, S. W.
Fulton, R. A.
Gambrell, F. L.
Garon, A. J.
Gesell, S. G.
Gilbert, Engel
Glasgow, R.
Glasgow, Robert D.
Glass, E. H.
Gleissner, Bruce D.
Goble, H. W.
Gordy, Harold C.
Granett, Philip
Grayson, J. M.
Greenwald, Margaret
Guy, H. G.
Guyton, T. L.
Gyrisco, Geo.
Haas, C. Y.
Hadley, C. H.
Haenssler, G. J.
Hamilton, Clyde C.
Hamilton, Donald
Hammer, O. H.
Hansens, Elton J.
Harris, C. S.
Harris, J. S.
Hartley, R. O.
Hartzell, A.
Hawley, I. M.
Haynes, Harry L.
Heal, Ralph
Hoffman, J. R.
Hoffmaster, Richard
Horsfall, J. L.
Houde, W. J.
Hovey, C. L.
Huckett, H. C.
Hutchins, F. E.
Hutchinson, Martin T.
Jaynes, H. A.
Jennings, Cedric
Johnson, J. P.
Karsten, Kenneth
Kennedy, J. W.
Kerr, T. W.
King, J. L.
Kirkpatrick, A. F.
Kisliuk, Max
Knickerbocker, I. E.
Knutson, Herbert
Koblitsky, Louis
Krister, C. J.
Langford, Geo.
LaPlante, A. A.
Larson, N. P.
Leiby, R. W.
Leonard, M. D.
Lohr, A. D.
Long, John C.
Long, L. A.
Mail, G. Allen
Matthysse, John G.
McConnell, H. S.
Menusan, Henry
Merrill, L. G.
Miller, A. C.
Miller, J. V.
Minnick, P. W.
Moore, Warren
Mort, Don W.
Mundinger, F. G.
Nash, Kenneth B.
Nelson, F. C.
Nelson, R. H.
Osmun, John V.
Paden, J. H.
Packard, C. M.
Parker, Lawrence B.
Pass, Herbert A.
Pechuman, L. L.
Pepper, B. B.
Pepper, John O.
Perinchief, M. K.
Peterson, P. D.
Pickett, A. D.
Pierpont, R. L.
Piquett, Price G.
Plumer, Allison A.
Poland, J. L.
Poos, F. W.
Porter, B. A.
Porter, Richard P.
Preece, H. W.
Pyenson, Louis
Rapp, Frank
Rex, E. G.
Ridgway, H. W.
Riedeburg, Ted
Roark, R. C.
Rogers, Geo. H.
Roth, R. W.
Sacktor, Bertram
Sanders, J. G.
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Torpin, Paul D.
Turk, E.
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Turnipseed, G. F.
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Vandenberg, G. B.
Van Giluwe, John
Van Winkle, D. C.
Vincent, Rufus H.
Vinzant, J. P.
Waitze, Ruth
Walker, H. G.
Wallace, Phillip
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Washburn, Lloyd
Weiss, Harry B.
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Wheeler, E. H.
White, Ralph
Wilcoxon, Frank
Wilson, Clifton A.
Wood, Gilbert C.
Woodbury, E. N.
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ROGER F. ANDERSON AT LOS ANGELES

Dr. Roger F. Anderson, formerly at the Beltsville Laboratory of the Bureau of Entomology and Plant Quarantine where he was engaged in studies of forest insects has changed his address to the Division of Entomology, University of California, Los Angeles 24. We have no information about his new work.